USEFUL INFORMATION ON ELECTRIC LIGHTING.

BY

KILLINGWORTH HEDGES.

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TOTO CŒLO.

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PREFACE.

THE following pages were written at the request of several friends who, being connected with manufacturing interests, wished for some general information as to the practicability of introducing the electric light in preference to the system of lighting at present adopted.

Up to the present time the greater part of the information on electric lighting has been put forward either by persons connected with gas companies, who take rather a depreciatory view of the question, or by others who, from interested motives, are apt to exaggerate the merits of the new illuminant.

The plan suggested itself to the author of condensing into a very abridged form the principles governing magnets, currents, &c., and a general description of the arrangements necessary to carry these principles into practice.

As the work is intended for the use of public boards, manufacturers, and others wishing to adopt the electric light, it was thought as well not to insert any matter, however interesting, that did not tend to assist the object in view.

To facilitate reference the work has been divided into nine heads.

The 'Introduction' treats of the laws governing magnets and induced currents; also

an explanation of the arrangement of magnets, coils, &c., necessary to form an electric machine.

The heading 'Voltaic Arc' includes a cursory summary of regulators and the electric candle; also a description of carbons and of conductors. A few lines are next given to the subject of 'Division of the Electric Light' under 'Machines;' the principal types of each description are mentioned, but it was found impossible even to go into the details of these without trespassing into space.

A few types of the motors which are most likely to be used are briefly considered under the head of 'Power Required.'

The 'Application of the Electric Light' is a subject which, to do justice to, would require the whole of the space at our disposal. It is most important to intending users, as the profitable employment of the light will depend in a large measure on care having been taken beforehand to adapt it in such a way that its great power and intensity is not wasted.

The data given under 'Approximate Cost of Working' are of necessity rather bare. Electricity has not been employed long enough as a lighting agent to obtain statistics of the cost under many conditions. The author has selected those only which came from sources that may be depended on, and it is to be hoped that friends will contribute information under this head, particularly with a view of getting the experience of those who have taken the

matter up purely from a commercial point of view, with the hope of expecting more light at a reduced cost.

So many letters have appeared in the *Times* and other papers on the much disputed question as to the future of the gas companies that it is not thought necessary to say much on the subject. What is said may be taken as the author's disinterested view of the case.

A visit to the gasworks at Paris has strengthened the opinion previously formed that the useful products resulting from the manufacture of gas are of sufficient value themselves to pay for the cost of making the latter.

When in France the author also investigated several instances of exclusively electric lighting, and was accompanied by an English gas engineer, who was so much struck with the practicability of what he saw that he bought a machine, and now lights his factory by electricity.

The author is aware of a great omission in this work, which will be found out by those wishing to estimate the cost of introducing electric lighting.

It was found, however, impossible with fairness to give prices of the different systems, which in some cases are not settled. It may not be out of place to remark that there is no reason why a twenty-five per cent. increase on French prices should be exacted from the public here for the use of machines which bid fair to have considerable sale if supplied at a

reasonable price. This fact must be borne in mind on reading statements of the first cost of electric-light machines purchased and worked in France.

Those who wish for a history of the recent introduction of electricity for lighting purposes will find the subject already well described in various works.

At the present time, while electric lighting is one of the principal topics of the day, it is interesting to go back still farther, to the first experiments on this invisible something called electricity.

Nearly the earliest are those of Benjamin Franklin in the year 1747. They are well set forth in an old work entitled *Observations on Electricity, made at Philadelphia.*

The following is an extract from the preface by the editor, and is not an inappropriate description of the power of this most useful agent which is daily being called into requisition for some new field of labour :—

'He exhibits to our consideration an invisible subtle matter disseminated through all nature in various proportions, equally unobserved, and, whilst all those bodies to which it peculiarly adheres are alike charged with it, inoffensive.

'He shows, however, that if an unequal distribution is by any means brought about, if there is a coacervation in one part of space, a less proportion, vacuity, or want in another, by the near approach of a body capable of con-

ducting the coacervated part to the emptier space, it becomes, perhaps, the most formidable and irresistible agent in the universe. Animals are in an instant struck breathless, bodies almost impervious by any force yet known are perforated, and metals ignited by it in a moment.'

In conclusion, the author must apologise for bringing forward this work in such an incomplete form, but hopes to publish another edition, giving more information as to the cost of working the various systems, which will be of greater use to those who may desire to profit by the introduction of the electric light.

KILLINGWORTH HEDGES.

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WESTMINSTER.

December, 1878.

PREFACE TO SECOND EDITION.

THE first edition of this work becoming out of print, the author has had the original edition reprinted, and has added a few remarks on the gas companies' exhibition of improved street lighting and on the report of the trial of the electric light at the Gaslight and Coke Company's works at Westminster.

March, 1879.

PREFACE TO THIRD EDITION.

FOUR years have elapsed since this work was written, and in this short time electric lighting having passed out of the hands of the experimentalists has taken a recognised position as the illuminant of the 19th century. Its introduction, though more rapid, has not been without some of the difficulties and vicissitudes which attended its older rival gas. We are perhaps, entering the most important era in the history of the electric light: arc lighting, though undoubtedly a success, is of little benefit to the general public, who now are anxiously awaiting the further development of the incandescent light with which the introduction of electricity into our houses will only be a question of supply.

Although the matter contained in the preceding editions is to all intents applicable to the systems employed at present, it was thought better to rewrite the whole with a view of keeping the information of as practical a nature as possible.

A great deal has been written respecting 'electric energy,' and exaggerated accounts have been given as to what is to be accomplished by this marvellous force which is to enable us to utilise those sources of power at present valueless. On investigation it appears that after all this 'electric energy' is only a means by which power can be transmitted, and

although the term seems to express something mysterious the matter resolves itself into a question of pounds, shillings, and pence as to whether it is more economical to transmit the heat from coal or the power of a river by means of an electric current, an hydraulic pipe, or a wire rope.

As a preliminary introduction to this subject the author has added a chapter on the transmission of power, but this book having been compiled for those who wish to make use of electricity in its commercial form, many terms and formulæ are omitted which would be necessary in a work of more scientific pretensions. The nomenclature of the principal electrical quantities will be found under the head of 'Electrical Measurements.'

Owing to the courtesy of the editor of the *Electrician*, some useful Memoranda are given, which, with the following Table of Resistances, will be found of assistance in practical work.

In conclusion, he cannot do otherwise than express his thanks for the information he has obtained from the writings of Hopkinson and Conrad Cooke; also to Mr. Crompton for allowing him to have the results of his valuable practical experience.

January, 1882.

CONTENTS.

THE VOLTAIC ARC.

FIG. 1.

Light
Ethereal, first of things,
quintessence pure.

MILTON.

USEFUL INFORMATION

ON

ELECTRIC LIGHTING.

INTRODUCTORY REMARKS—THE PRODUCTION OF ELECTRICITY.

Magnets—Coils—Commutators—Interior and Exterior Resistance—Tension—Quantity.

IN order to acquire even a partial knowledge of the application of electricity to lighting purposes, it is first of all necessary to learn the A B C; namely, the natural laws which govern the action of all dynamo- and magneto-electric machines.

Faraday found by numerous experiments that if a bar magnet is introduced into a bobbin or coil of insulated wire, it determines an electric current therein. He also found

that when a circuit is traversed by an electric current of a certain direction, and there is approached to it another circuit not traversed by a current, there is created an electric current in the second circuit which is in the opposite direction to the first. The term circuit is used to denote the path of an electrical current out and home again.

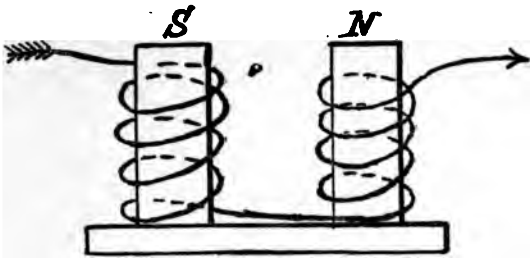
Currents developed by the influence of a magnet or of an electrified circuit are termed *induction currents* or *induced currents.* The magnetised bar, or the first current, is termed the inductor or inducing current.

Magnets are of two kinds :—

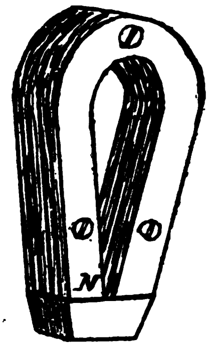
1. *Permanent magnets*, in which the amount of magnetism is fixed. These are found to be more powerful when built up of several plates of steel than when made of a solid bar.

2. *Electro-magnets*, which remain magnetic only when a current is passing round them, with the exception of a small amount of permanent magnetism which they acquire. This is called *residual magnetism.* A coil of wire through which a current is passing exercises an attractive action on a piece of iron introduced

pp. 2-3.



Electro-Magnet.



Permanent Magnet
and Armature.

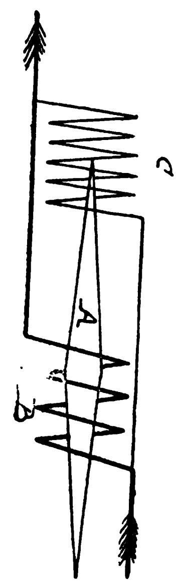
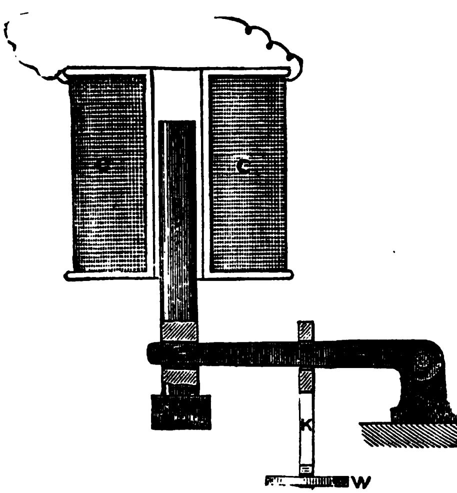


Diagram of Solenoid
in Pilsen Lamp.

A Plunger.
B Coil of low resistance.
C Coil of high ,,
See page 16.



Solenoid of Brush Lamp.
C Coil. P Plunger.

into the coil. Such a combination is known as a *solenoid.*

Magnets are said to have two poles, north and south.

Dissimilar poles attract; similar poles repel.

Solenoids act in the same way; if the north pole of a magnet be introduced into the south pole of a solenoid it will be sucked into the latter, although the south pole of the magnet is being repelled upwards, but with less force.

Effect of a Magnet on an Induced Coil.

By an induced coil or bobbin is meant one or several lengths of insulated wire wound round a core of iron of suitable form.

1. When a coil is made to approach the pole of a magnet (in practice by revolving it as near to the magnet as possible), the latter causes a current to be set up in the coil in the opposite direction to the current in the inductor.*

* Considering a magnet as a solenoid after Ampère's theory. This experiment can be easily tried by making a galvanometer by winding a piece of covered wire round a common pocket compass; an ordinary toy magnet will be found sufficient to send a current through a small coil.

2. If the same coil is withdrawn from the poles of a magnet, the current produced is in the opposite direction to when it approached.

3. When a coil approaches the south pole of a magnet, the current induced is of the same direction as that caused by withdrawing it from the north pole.

4. If the coil approaches the north pole the effect is exactly opposite to the last case (3).

To produce the quantity of electricity desired, a series of induced coils or number of bobbins are caused to revolve either between or before the poles of one or more magnets, which by the action of the above described laws set up a current in the coils or bobbins. The whole thus arranged constitute an electric machine.

In all modern machines the electricity is generated by having fixed magnets and causing the coils or bobbins to revolve either in front or between these magnets as near as possible without touching.

Machines used for producing electricity in sufficient quantity for electric lighting may be

divided into two classes, magneto-electric and dynamo-electric.

Magneto-electric machines are those in which the current of electricity is generated and started by the magnetism contained in the permanent steel magnets.

Dynamo-electric machines are those in which the dynamical force is converted into electricity, which is gradually augmented in intensity. The residual magnetism contained in the iron cores of the electro-magnets first sets up a feeble current in the induced bobbins or coils. This feeble current is passed round the coils of the electro-magnets, thus rendering them more powerful, and causing them again to react with greater power on the induced bobbins. This action goes on until the limit of saturation of the magnets is obtained. To the electro-magnet ends are generally connected the wires leading to the lamp or other apparatus where the current is to be utilised.

The application of electro-magnets, besides adding considerably to the power of the machine, has led to a diminution of their bulk and also of their costliness.

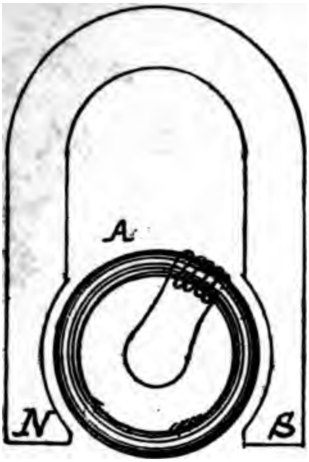
The power of the old form of magneto-electric machines is fixed by the number of magnets employed; these become more feeble by use, and eventually must be re-magnetised.

On revolving an induced coil between the poles of a magnet, the same action takes place as when two galvanic batteries of the same number of cells are opposed to each other by poles of the same name. The sum of the currents on one side is equal to the sum of the currents on the other, and no action takes place. To start the battery it is only necessary to communicate by an electric circuit with the two points where the series of cells are opposed. Both batteries immediately work together and give a current equal to their united strength.

Machines are said to give alternating or direct-acting currents according as the current produced in the conductors or wires by which the electricity is taken to the lamp travels continuously in one direction or changes almost instantaneously all the time from one direction to another.

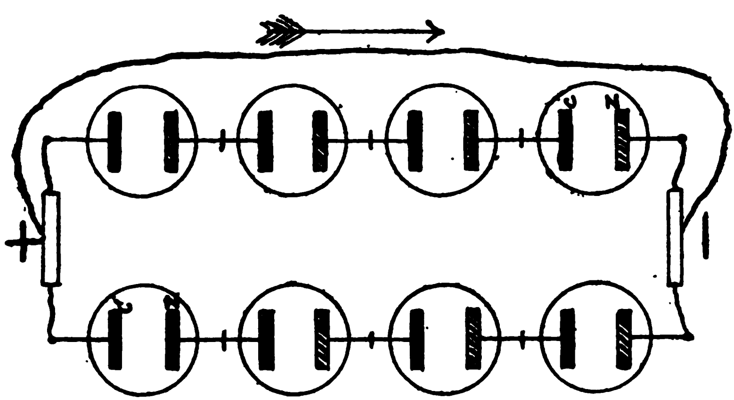
If two bobbins are united (as in the case of an ordinary electro-magnet) and revolved

pp. 6-7.



Action of Gramme Machine.

A ring of soft iron surrounded with a spiral of insulated copper wire. Revolving A will produce a current in the closed circuit of the copper wire. in an alternating direction.



Two sets of voltaic batteries placed in opposition but joined together in quantity.

before the poles of a permanent magnet, the current set up in the bobbins is alternating in direction. This is shown in practice by the action of Holmes' lighthouse machine.

Commutator.

In order to collect these alternating currents as generated and deliver them as continuous, recourse is had to an instrument called a commutator, which is really a collector of the electric currents.

As it is generally called the commutator, however applied, it will be better to describe it under that name, although what is generally understood by a commutator is an apparatus for changing the direction of the current. As this is the part of the machine most affected by wear, attempts have been made to do away with it, but have not been practically successful.

It consists of a number of plates of metal fixed radially round the shaft of the machine, each plate obtaining its electricity from the coil or coils supplying it, but being isolated from its neighbour by means of some non-conductor.

Commutators require some attention, the surface of the brass plates becoming rapidly

abraded if many sparks are formed. The whole of the electricity developed in the machine is generally passed through them, and is collected by means of metal brushes. These brushes should be adjusted so as not to bear too hard, and a little oil may be used to diminish the friction. In the most modern machines the pressure of the brushes is regulated by a spring which can be eased by a screw with an insulated top.

When once set in the position where the least amount of sparks are formed the screw should not be altered except when the brushes are removed for cleaning. The machine when running with the brushes adjusted, and wire leads connected to the positive and negative terminals, is said to be in *open circuit*, and no current is produced. To obtain this it is necessary to close the circuit with a suitable resistance for the path of the current, which is termed *external*, to distinguish it from that of the coils, armature brushes, &c., of the machine, which is known as its *internal resistance*.

To close the circuit without giving work for the current to perform would be fatal to the machine itself, and would destroy the insulation

by heating; the amount of external resistance that can be overcome depends on the kind of machine employed and its internal resistance. Machines must have some internal resistance to produce a current at all, and those which have just sufficient internal resistance to enable a stable arc to be maintained will convert the greatest amount of power into light. It is very convenient to call the currents given by machines having low internal resistance *low tension* currents, and those having high internal resistance *high tension* currents. This effect is generally produced by winding with either thick or fine wire; those having thick wire are generally said to give a *quantity* current, and only one arc can be burnt in circuit, while the fine wire increases the *tension* and enables several arcs to be maintained.

The effect of quantity and intensity has been compared to two vessels, each holding the same amount of water, but one being flat and shallow and the other tall and narrow. The water in the latter would, if let out, be discharged with much more force than out of the former.

A machine is said to develop a current of

high electro-motive force when several arcs are maintained.

The electro-motive force of the current naturally increases with the velocity of rotation of the machine.

The Voltaic Arc.

Regulators—Electrodes—Conductors—Contact Breakers—Switches—Artificial Resistances.

This is the usual method of obtaining the electric light. It is produced by approaching one to the other the two conductors (generally the carbons) of a sufficiently intense electric source until they touch, and subsequently gradually separating them. An extremely brilliant luminous arc appears, and remains so as long as the distance between the conductors is not too great. (See fig. 1.) The colour of the arc varies with the substance of the electrodes or terminals of the conductors. It is yellow with sodium; white with zinc; green with silver.

The appearance of the focus depends especially upon the form of the electrodes.

The maximum length of the focus depends on the intensity of the current of electricity.

The voltaic arc obeys the laws of currents, and can be diverted in any direction by the action of a magnet.

The two electrodes or carbons are said to be either positive or negative; that on the end of the conductor by which the current passes from the machine being called the *positive*, and that on the conductor by which it returns the *negative*. With direct currents the carbon on the positive side burns away at double the rate of that on the negative. The former has a much higher temperature than the other, and whilst the negative carbon is only heated to dull redness, the positive carbon is heated to whiteness for a considerable length. With alternating currents both carbons are equally consumed.

The burning away of the carbon can be almost entirely prevented by producing the voltaic arc in a vacuum.

The voltaic arc is actually a portion of the electric circuit or current, passing from and

back to the machine, and possesses the properties of all other parts of the circuit.

The plan of working one light from a machine was the first introduced, and still may occasionally be used with economical effect where a very large amount of light is required; but without the light can be placed sufficiently high so as to extend over a large area, it is generally found more advantageous to employ two or more lights on the same circuit from each generator. Splitting up the light thus entails some loss, caused by the inverse or contrary electro-motive force set up by each arc.

Recent improvements enable several lights to be worked on one circuit, any of which can be extinguished without interfering with the others by means of a cut-out, which causes the current to pass by. With the voltaic arc means must be taken to compensate for the loss of carbon consumed, and various forms of instruments, called *regulators*, have been adopted.

Regulators.

Electric lamps or regulators are all designed for the same object, which is to keep the dis-

tance between the carbon points uniform, and to maintain the necessary movement gradually and without oscillation. That they all do this the author cannot affirm, and some judgment is required in selecting an efficient regulator, and also not to get an obsolete pattern. The large variety of electric lamps now brought forward, many of which are simply revivals of old schemes dating back to 1844, renders it impossible to do more than briefly describe those which are in practical work. They may be classed as follows under two heads:—

No. I. Those intended to burn singly.

No. II. Those arranged so that several lights can be maintained on a circuit.

To Class I. belong the balance lamps in which the carbons are kept at a fixed distance apart, by means of a balance weight or spring acting against the pull of an electro-magnet. Types of these are the Serrin, Lontin, Siemens, Alteneck, Jaspar.

Nearly all the early kind of lamps belong to this class, which really also embraces many of the No. II. type, which, of course, can also be burnt singly.

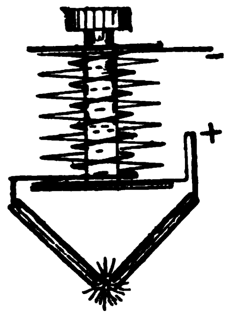
No. II. The various means by which several

arcs are maintained may be reduced to three heads, which are *Differential*, *Derivational*, and *Mechanical* feed lamps.

The differential arrangement was first applied by MM. Zacassaque and Thiers in 1856. It consists of regulating the feeding, not by the absolute strength of the current passing through the lamps, but by the difference between this current and another wire connecting the two terminals directly. Thus a short circuit is formed by a small portion of the current passing through a fine wire resistance in such a way that magnetism is induced, so as to weaken the magnet or solenoid, which is formed by the current passing through the arc. Thus, if an excess current passes and the arc becomes too long, a larger amount passes through the shunt circuit, weakens the magnet, and causes the carbons to approach.

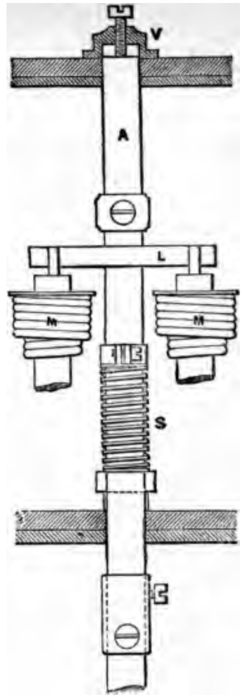
The clutch lamps are with one exception of this class. In these the top carbon holder is prolonged as a round rod, which is seized and lifted by a clutch actuated by an electro-magnet or solenoid, which establishes the arc and regulates the descent of the upper carbon.

Types. The Brush, Weston, and Andrews.

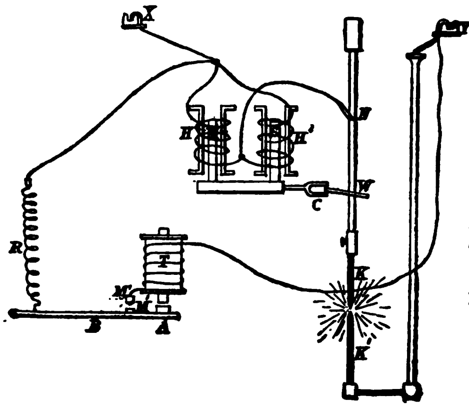


Differential Solenoid
in Hedge's Lamp.

The fine wire resistance is wound over the thick coils of the Solenoid.



Carbon Separating Magnet
Crompton Lamp.



Skeleton diagram of Brush Lamp and Short Circuiter.

X Y Terminals of Lamp.
H H Solenoids.
N Carbon Holder.
W Washer Clutch.
T Electro-Magnet wound with thick and fine wire.
M M Contact Pieces, causing current to pass through thick coil of magnet and resistance, R.

In the first two the differential arrangement is practically the same, with the exception that in the Brush a solenoid is used and an electro-magnet in the Weston. In both cases inequalities of sudden movement are provided against by the use of a dash pot. This is done away with in Andrews' lamp by the use of two electro-magnets pulling on two armatures with opposite effect, one magnet being in the main and the other in the shunt circuit. By the use of cast iron armatures the lamp feeds perfectly steadily, and is less liable to get out of order than either of the two preceding ones.

Carbons 11 or 12 $^m/_m$ in diam. are generally used with this description of lamp.

Siemens' pendulum lamp also belongs to this class, when fitted with a differential arrangement. It is chiefly used with alternating currents, which pass round a solenoid connected with a movable frame, on which is fixed a pinion, regulated by a pendulum. When the arc becomes too large the pendulum is free to move, and the upper carbon descends regularly to the proper distance. A second solenoid is traversed by the shunt current and neutralises the action of the first; 10 $^m/_m$ carbons are used.

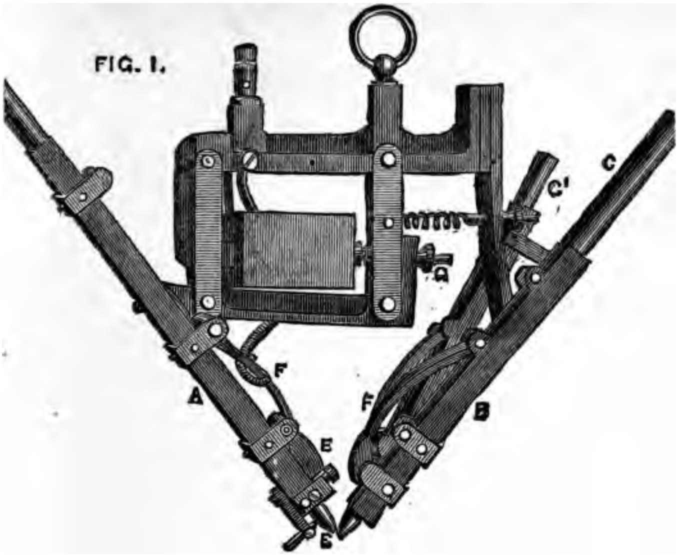
The Pilsen lamp, which was shown working successfully in connection with the Shuckert machine at the Paris Exhibition, is a sort of compromise between a Brush and Siemens plunger lamp, with the addition of the conical shaped core of the solenoid, which constitutes the novelty in this system. The inventor found that by making two plungers this shape and opposing one to the other in two solenoids wound with thick and fine wire, any variation in the current passing round the coils caused the plungers to be affected in a more sensitive manner than if of the ordinary circular shape. The simplicity of this system is done away with on the present lamps by the many additions found necessary in practical work.

Gravity Lamps.

Regulators in which all mechanism for feeding the carbons as they waste is done away with, the action of gravity alone controlling the descent of the carbons. Hedges', which consists of two troughs, in which the carbons slide loosely until they meet one another at the apex of a letter V, the arc being formed at their points when separated.

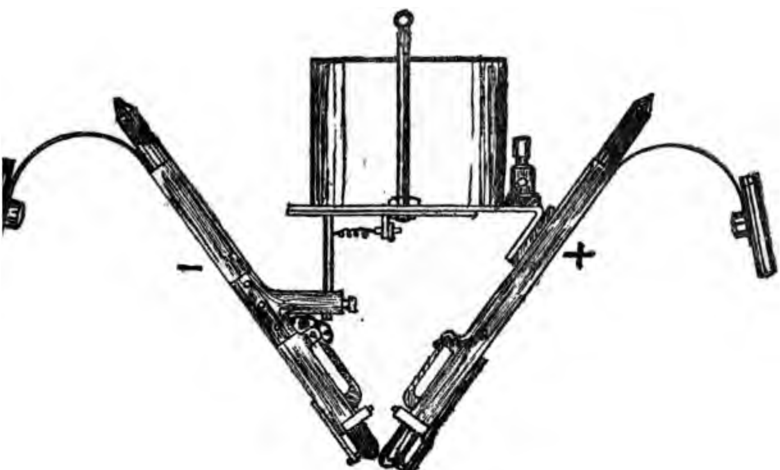
pp. 16-17.

FIG. 1.



Hedges' Three Trough Lamp.

A Negative Carbon.
B Trough containing Positive Carbon. C Supporting Carbon.



Hedges' Two Trough Gravity Lamp and Weights.

On the positive side the carbon is supported by a smaller one sliding in a tube and meeting it near the point. This small carbon wastes very slowly by the heat from the larger, and allows the latter to descend. The negative is kept up and maintained in the same position by an adjustable stop. The separating arrangement is effected by a solenoid in the main circuit; and an electro-magnet in the shunt circuit, acting against the end of the plunger of the solenoid, gives a differential action and regulates the length of the arc. In another form a solenoid alone is used with a fine wire coil to neutralise. Contact is made at the lower end of the carbons by a weighted piece of metal which is slightly hollowed. The lamp differs from all others in this important point: the resistance of the electrodes is always the same, whatever lengths are used, so that carbons a metre long to last sixteen hours may be employed. 13 or 14 $^m/_m$ carbons are used.

In a modification of this lamp up to 1000 candle power only two carbons are used, the positive being supported by an iridium stop, while the negative has a steatite one. Rapieff's lamp, which is often included in this class, is

not a gravity lamp at all, as it is dependent on cords actuated by a weight. An electro-magnet separates the electrodes, which each consist of two carbons meeting at an angle thus $\substack{\vee \\ \wedge}$; one pair placed above the other. This lamp has nearly always been used for alternating currents, which are far easier to regulate than continuous ones.

Derivational Lamps.

In this type the regulative arrangements for burning in series are independent of the strength of the main current, which simply establishes the arc. The only two kinds in actual work are the Crompton and the Gramme.

The positive carbon in the Crompton lamp is fixed to a massive holder, consisting of a brass rod, with a rack cut in its side, which engages in a train of wheels. An electro-magnet separates the carbons to a fixed distance, which is regulated when starting. The descent of the upper carbon holder is caused by a small brake wheel, the brake being connected to the armature of a magnet, wound with fine wire and of high resistance, connected to the two terminals of the lamp. A most

delicate adjustment is thus obtained, and the lamps maintained very steady. Gramme's lamp is very much the same, only the movements are brought about in a more complicated manner, which makes it more bulky and expensive than Crompton's. 13 and 14 $^m/_m$ carbons are generally used.

Mechanical Feed Lamps.

The only one of this class is the Brockie. The separation of the carbons is brought about by a clutch in the usual manner, but the regulation is controlled by a revolving commutator which is actuated by the same motor which works the generator. At certain intervals the current is cut out of the electro-magnet, and the upper carbon falls on the lower, to be raised again instantly to the regulated distance. A very ingenious arrangement has been designed by Mr. Brockie by which two sets of carbons are actuated by one magnet, one set burning after the other is exhausted. 13 $^m/_m$ carbons are employed.

With the exception of the Siemens continuous current, Hedges', and Rapieff's, all the lamps in the two latter classes are non-focussing;

that is to say, the bottom carbon is a fixture, and the position of the arc is lowered as the carbon becomes consumed.

In the Siemens lamp the lower carbon is pressed up against a copper ring by means of a weight acting on its base in the same way as a spring presses up a candle in a carriage lamp. Although a focussing lamp is not altogether necessary, it should be employed where objects are likely to throw shadows by the change in the position of the light. The Siemens pendulum lamp can also be used for alternating current; the others as described are usually employed with continuous. For military and naval purposes a lamp in which the carbons are brought together by a right- and left-handed screw, turned by hand, has hitherto been used, but will probably soon be discarded for a self-regulating kind.

It is difficult to say which is really the best form of lamp: this can only be arrived at after a lengthy trial under varying circumstances. Simplicity is of the greatest importance, and fewness of parts; these should be interchangeable, with spare pieces kept in readiness. Experience tends to show that for in-door pur-

poses the Crompton, in careful hands, is all that can be desired. For out-door or workshop use the Brush, Andrews, or Hedges are less complicated; while the latter may be employed with advantage in a foundry or rolling mill, as it can very readily be cleaned.

Brockie's is the only lamp which gives satisfactory results with an engine going at a slightly irregular speed, but the 'blinks' at regular intervals are at first a source of annoyance.

Candles.

The voltaic arc is also utilised for lighting purposes by means of;—candles.

In every description of electric candles two carbons are placed side by side, and as the current employed is always an alternating one each is burnt away at the same rate. Electric candles may be divided into two kinds: those with an insulating material between the electrodes and those without this. Of the first description the Jablochkoff candle is the only kind in work practically. Its first introduction was heralded by a great panic among the holders of gas shares, but although decidedly

the system has been carefully worked out its use has not extended considerably here.

This candle is usually inclosed in a thin opal shade, which immediately reduces the effective light from 300 to 180 candles. As applied in Paris, this effective light is again reduced by a portion of the rays striking upwards and illuminating the tops of the houses as much as the streets below. This loss would be considerably less if a reflector of a sufficient size to throw down the upward rays was employed.

The manufacture has been greatly improved and a self-acting arrangement completed by which one candle when burnt low enough lights up its neighbour without the attention of a lamplighter every two hours to watch the current. Kaolin, which was first used for the insulating material, has been abandoned in favour of a mixture of baryta and lime. The light from these candles is enhanced by the incandescence of the insulating material, but without this burns away regularly the steadiness is sacrificed.

The second kind of candle has no insulating material; the length of the arc is fixed by the distance the carbons are allowed to sepa-

rate at the points through the action of an electro-magnet: to this class belong the Wyld and Jamin candles. In the former the arc commences at the top of the carbons and burns downwards, while in the latter the whole apparatus is inverted, and the arc starts at the lower end of the carbons. The natural inclination is to run upwards, but this is neutralised by the action of a coil of insulated wire through which the current circulates, and keeps the arc at the points of the carbons. These candles also relight themselves automatically if blown out by the wind or by the stoppage of the current. The arrangement is very simple, and consists of a small electro-magnet, which comes into action directly the current passes, and brings the two sticks of carbon to the proper distance apart. Directly the current stops the carbons touch and the light is again established.

The carbons used in the Jablochkoff system are 4 $^{m}/_{m}$ in diameter, and are consumed at the rate of nine inches per hour for each light.

The Wyld system might be made especially suitable for street lighting, the carbons being arranged so as to be replaced from a

sort of reservoir of spare ones fixed in the upright of the lamp-post.

There is one other lamp which is known under the name of the Lampe Soleil. This system is a sort of connecting link between arc and incandescent lighting. The light mainly arises from the incandescence of a block of marble which is maintained intensely hot by causing an alternating current from the voltaic arc to pass from one carbon to another over its surface.

Although the colour of the light is, as its name implies, that of sunlight, the quantity given out is much less than that from any other system employing the same power.

Electrodes.

Carbons are now universally used as the electrodes or points where the voltaic arc is to be produced. They have undergone very great improvement lately. As originally introduced, they were sawn out of simple pieces of graphite (a deposit left sticking to the sides of the gas retorts after they have been worked some little time), and were found to be so full of impurities that a flickering of the light, and

sometimes a total extinction, was caused. The best carbons now are either made of coke or graphite powdered extremely fine and compressed, or from the residual products left after the distillation of petroleum. The process as carried on here is briefly as follows :—The material to be used is ground to an impalpable powder, and, having been incorporated with any foreign substance which may be employed to tone or colour the light, is then made into a paste and pressed through discs to form the rods or candles of the required size. After being slowly dried at a low temperature, each batch of rods is dipped in a saccharine mixture and then baked in a furnace at a very high temperature. This process is repeated until all the pores of the rod are filled up with pure carbon, and a homogeneous mass is the result.

A good carbon should ring when struck, and should be perfectly similar in diameter throughout its own length. Straightness is also very desirable. It is customary to use the bent rods up in lamps taking short pieces.

The resistance of the carbon electrodes is of importance especially where the current has

to pass through long carbons. A useful standard is the resistance of a good carbon 1 millimetre in diameter, which has been found to vary from 40 to 50 ohms per metre; from this the resistance of any larger size can easily be calculated. According to some careful experiments by Dr. Werner Siemens the conductivity of a carbon increases with a rise in the temperature. This is contrary to the rules laid down by Auerbach and others, who have considered carbon to follow the law of metals and decrease in conductivity.

Carbons are made in all lengths up to a metre, and from all diameters from 1 milli metre to 20 $^{m}/_{m}$.

Hard carbons resist the action of the electric current better than soft ones, but, in comparison, give a less brilliant light and expend more motive power. Soft carbons give a bright light, but make much dust, and are subject to splitting and throwing off splinters. Carbons are sometimes coppered over to afford less resistance to the passage of the electric current. It is not advisable to use these except in large spaces where ventilation is good on account of the poisonous fumes.

If a coating is necessary either nickel or iron is the best. According to M. Carré the addition of the latter enhances the value of the light in the proportion of 1·6 or 1·7 to 1. Iron, either as a coating or as an oxide, produces a pleasing change in the colour of the electric light; a somewhat similar effect is produced by using cored carbons, which have a small hole up the centre, filled up with a soft composition which is fused by the heat of the arc, and insures the steadiness of the light. The steadiness of arc lights is only to be depended on when good carbons are used. Until lately there has been considerable difficulty in getting carbons from any maker from time to time which had always the same resistance, and which could be relied on to give the same results as previous lots. With the greater extension of arc lighting this defect is becoming remedied, and what is more important the monopoly of manufacture which the French have enjoyed for some time is being broken up with a corresponding lowering of price.

The principal kinds of carbons made in England are Siemens', Gray's, Johnson & Phil-

lips', and Hedges'. In America the Brush carbon is almost universally employed. Those of Siemens are of a hard nature and of high resistance, but can be employed with their continuous current machines. With alternating currents where great steadiness is necessary the cored carbons made by the Berlin firm of the same name are always used.

Gray's carbons manufactured at Silvertown are well made, and are remarkably free from noise; but they sacrifice light in order to maintain silence, give considerable ash, and often evolve gas at the arc, making it long.

Johnson & Phillips are now producing carbons which are said to be equal to the best French make.

Hedges', as originally made, were not found suitable for use in lamps with currents of high electro-motive force, as the carbons were too soft. They contain iron which gives a warmer appearance to the light: this can be seen by observing the effect at the Cannon Street station, where these carbons are used, and comparing it with that at Charing Cross. The Electric Lighting Supply Company, who manufacture these carbons, have adopted a new

process by which they can now be produced suitable for use in any lamps.

The manufacture of carbons on the Brush system is now commenced here, but has not been started a sufficient time to make a comparison with those sent from America, which are singularly pure and burn with great regularity. The resistance of the Brush carbons $11^{m}/_{m}$ in diameter varies from 5 to 7 ohms per metre. In France M. Carré stands pre-eminent as the oldest manufacturer and inventor of the carbons for which his firm have been long celebrated. These carbons are beautifully straight, and can be had in any lengths up to a metre, and from diameters varying from $1\ ^{m}/_{m}$ to $18\ ^{m}/_{m}$. The great drawback to their use in this country is the high price charged and the difficulty of getting orders filled quickly.

Next to Carré come Sautter and Lemonnier, who also produce good carbons, but inferior in finish to the older maker.

The sizes most used are $12\ ^{m}/_{m}$ ($\frac{1}{2}$ inch in diameter) and $13\ ^{m}/_{m}$; the latter is consumed at the rate of about $3\frac{1}{8}$ inches per hour, or $2\frac{3}{4}$ for the positive and $1\frac{3}{8}$ for the negative carbon.

If the rate is faster than this it shows that either the current is too powerful for the diameter or that the carbons are being wasted.

Conductors—Insulators.

Conductors or leading wires abbreviated to *leads* are usually of copper wire, and made of a number of small wires arranged in groups. The diameter and number of wires increase according to the distance from machine to lamp. In ordering leading wires or cables the copper should always be specified to be at least 96 per cent. of the conductivity of pure copper: this percentage will be guaranteed by good makers.

The exact area necessary can only be ascertained by knowing what resistance is best suited for the special machine to be used. For instance, with the **A** Gramme machine the total external resistance should not exceed 1½ units. Taking the resistance of the arc in the lamp to be equal to one unit, the resistance of the leads to and from the carbons must not be more than half a unit or ohm.

Double the quantity of leading wire will be required to allow for return to machine.

ELECTRICAL RESISTANCE OF COPPER WIRE IN FRENCH MEASUREMENTS.

B.W.G No.	Diameter in Millimetres	Area in Millimetres.	Circumference in Millimetres.	Metres per Kilogramme.	Kilogrammes per Metre.	Resistance in Ohms		Kilogrammes per Ohm.	Metres per Ohm.
						per Kilogramme.	per Metre.		
1	7.62	45.6	23.9	1m95	0k514	0.00073515	0.000377	1360	2652
2	7.21	40.8	22.6	2.78	0.360	0.00116760	0.000420	860	2379
3	6.58	34	20.7	3.33	0.300	0.00168165	0.000505	595	1980
4	6.04	28.7	19	3.95	0.253	0.00232260	0.000588	430	1700
5	5.59	24.5	17.6	4.61	0.217	0.00322700	0.000700	310	1430
6	5.16	21	16.2	5.43	0.184	0.00452319	0.000833	220	1200
7	4.57	16.4	14.3	6.90	0.145	0.00731400	0.00106	137	945
8	4.19	13.8	13.1	8.20	0.122	0.01025000	0.00125	98	802
9	3.76	11.1	11.8	10.20	0.098	0.01581000	0.00155	63	646
10	3.40	9.1	10.7	12.50	0.080	0.0237500	0.00190	42.20	527
11	3.05	7.3	9.6	13.50	0.074	0.0318600	0.00236	31.40	424
12	2.77	6	8.7	18.87	0.053	0.0539682	0.00286	18.60	350
13	2.41	4.6	7.6	24.80	0.0403	0.0932480	0.00376	10.70	266
14	2.11	3.5	6.63	32.40	0.0309	0.160380	0.00495	6.26	202
15	1.83	2.63	5.75	45.10	0.0232	0.294954	0.00654	3.40	153
16	1.65	2.14	5.18	52.90	0.0189	0.430077	0.00813	2.30	123
17	1.47	1.70	4.62	69.40	0.0144	0.73564	0.0106	1.35	94.5
18	1.24	1.21	3.90	94.30	0.0106	1.33906	0.0142	0.75	70.4
19	1.07	0.9	3.36	135.10	0.0074	2.60743	0.0193	0.38	51.9
20	0.89	0.62	2.80	181.8	0.0055	5.05404	0.0278	0.20	36
21	0.81	0.51	2.54	212.8	0.0047	7.04368	0.0331	0.14	30.2
22	0.71	0.39	2.23	285.7	0.0035	12.37081	0.0433	0.08	23.1
23	0.63	0.31	1.98	364	0.0028	19.6924	0.0541	0.05	18.5
24	0.55	0.24	1.73	465	0.00215	32.5500	0.0700	0.03	14.3

For Table of English Measurements see page 152.

p. 31.

The following table shows approximately the diameter of the conductor for different resistance, so that knowing the distance the size can be easily found :—

Weight of Conductor in lbs. pr 1000 yds	134	168	251	335	419	236	149	97
Diameter of Conductor.	·140	·155	·190	·220	·245	·196	·152	·115
Resistance in units pr 1000 yds	2·350	1·860	1·240	·940	·760	1·35	1·94	4·40

The size found will only be approximate, but will be near enough for the purpose. If the exact area is required, that of a single strand of wire must be calculated and multiplied by the number twisted together. *Vide 'Table of Electrical Resistances of Copper Wire.'* The small wires are generally expressed by the Birmingham wire gauge number; the same table will facilitate the calculation by converting the B.W.G. into inches or millimetres. The resistance of annealed iron wire

is about six times as great as copper, and that of german-silver thirteen times. The resistance of all metals increases as the temperature increases, so that where accurate results are required the resistance must be calculated at the working temperature.

In many cases the return cable can be dispensed with altogether by attaching the lamp end to a gaspipe or ironwork of a roof, and also connecting the machine to the same conductor.

The hydraulic mains used in docks or ordinary waterpipes make excellent conductors, but care must be taken to see that the joints of the pipes are not insulated, the safest way being to bridge over all joints by means of a short piece of copper wire soldered to the two flanges. The earth itself will act for the return as in telegraphy; but without an earth plate of large surface be used and kept sufficiently moist, the current often fails.

Conductors are insulated in various ways. In some cases naked copper wires may be used, and if of small diameter they may be solid, but are much easier to handle if made up of several strands. Such leads would be insu-

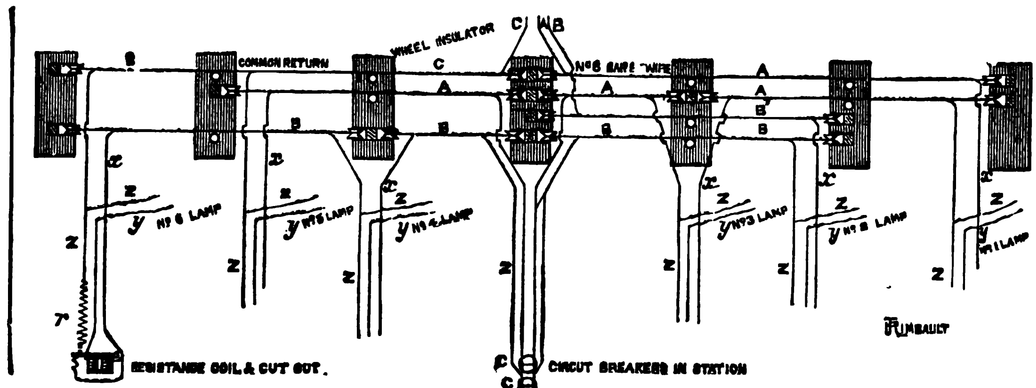


Illustration of the Connections of the Circuit for each platform at King's Cross Station.

Here A and B are the two flexible leading wires coming from the Bürgin machines through the station roof to supply the six platform lights, and C is the return wire common to both circuits. Lamps Nos. 1, 3, and 5 belong, as will be seen, to the A circuit, and Nos. 2, 4, and 6 to the B circuit. To prevent the failure of any lamp in circuit affecting the rest, each is provided with an automatic 'cut-out,' which cuts the lamp out of circuit and substitutes an equivalent resistance. As will be best seen at the left-hand side of figure, *x x* are flexible wires leading from the line to the cut-out, *y y* similar leads from the cut-out to lamp, and *z z* return flexibles from the lamp and the equivalent resistance coil to the line.

lated in the same manner as the telegraph lines, but the insulators should be of the best brown stoneware and of extra strength. The ordinary shackle form is, perhaps, the most convenient and easiest to fix. In all cases where wires are near buildings, or are likely to be handled, they should be carefully covered with some insulating material.

The wires should not anywhere be near the surface, and the insulating material should be pliable, to allow of bending the conductor round corners.

The best insulating material is gutta-percha, which is laid on next to the bare wires: this can either be protected by a taped or braided covering. Without the tape is put on very carefully, as in Gray's cable, it is liable to come unwrapped by the action of the wind. On the whole, braiding is the most durable, especially if thoroughly soaked in ozokerit or paraffin wax after being finished.

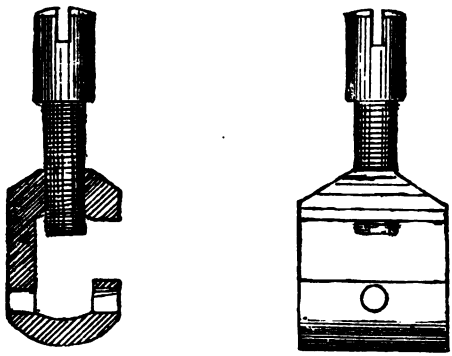
In many cases the conductors have to be taken underground, and if electricity is to be supplied like gas this plan will have to be universally adopted, as it is extremely dangerous to lead electric light wires over houses or where

they can by any chance come in contact with metal. It is at the same time necessary to take as much care with the insulation and protection of underground wires as if they were laid in water, the extinction of the lights of one system in the City being entirely due to the faulty insulation of the cable employed. It is not absolutely necessary to protect the exterior of the conductor if this is laid in pipes or wooden troughs, but the cost of using iron wire sheathing is not great, and may be used to take the return current through. The following is a specification of a cable designed by the author for the permanent instalment of the electric light in the Liverpool docks: for convenience this cable is laid under water, a similar one having been used at the Ipswich docks to work a light 450 yards away from the other lights in the same series.

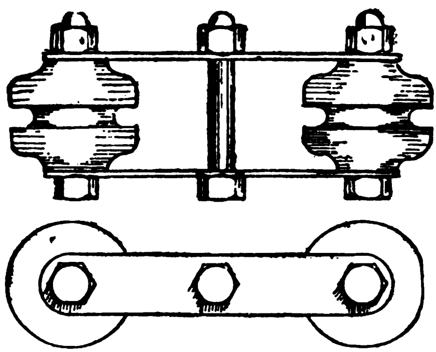
'Cable consisting of a strand of seven copper wires, each 0·068″ in diameter, insulated with gutta-percha to 0·445″ diameter, served with tarred jute yarn, sheathed with 20 galvanised iron wires of each 0·098″ in diameter, and externally protected with one layer of tarred jute yarn and two coatings of compound.'

pp. 34-35.

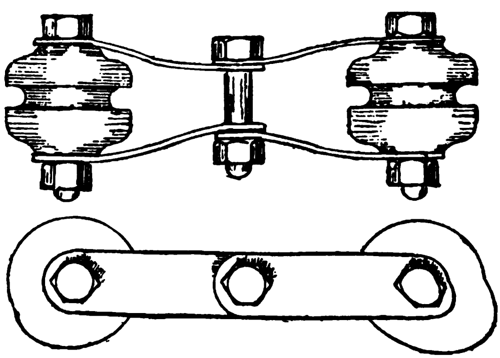
The Electric Lighting Supply Company's Special Connectors for joining leads or for uniting main to branch cable without cutting the former when a number of Incandescent Lamps are worked.



Shackles with Stoneware Insulators.



Jointed Shackle for turning corners.



A new form of cable covered with successive coatings of lead put on by hydraulic pressure in the form of a lead pipe was shown at the Electrical Exhibition at Paris, and is said to give good results.

In some cases a lamp is suspended by its conductor; a good form of the latter is that used in France: by slightly enlarging the conductor the return wires are carried in the inside and insulated from the others which surround them. One end of this conductor is attached to a small windlass which is insulated. The lamp can be thus raised or lowered without affecting the light.

For incandescent lights small copper wires are used carefully insulated—in many instances two wires are bound side by side so as to form a flat cable through which the current circulates to and from the lamp, especially when the lamp is on the old gas fittings. Where practicable the return current may be taken by the gas pipes. The leading wires from the machine should be of sufficient length to offer a resistance depending on the number of lamps employed. If the machine is connected up with a wire of too high resistance, there is a danger

of destroying the insulation by heating, which if excessive may also set fire to any inflammable material.

Insulators are those substances which give a high resistance to the passage of the current, and to all intent prevent it from passing. For constructive purposes in lamps and machines vulcanised fibre and a new material of a similar nature known as gelatinised fibre are the best; other substances, such as vulcanite, mica, water glass, are also employed.

Switches—Contact Breakers—Cut Outs—Resistances.

A *switch* is practically the same as a *contact breaker* with the exception that the latter, as its name implies, simply interrupts the current on its way from the machine and takes the place of the tap by the gas meter, while the former enables the direction of the current to be changed. A *switch* resembles a two-way gas tap, and acts by a brass contact piece sliding on and off two fixed pieces, each connected to one of the wire leads. It is very necessary to avoid sparks as much as pos-

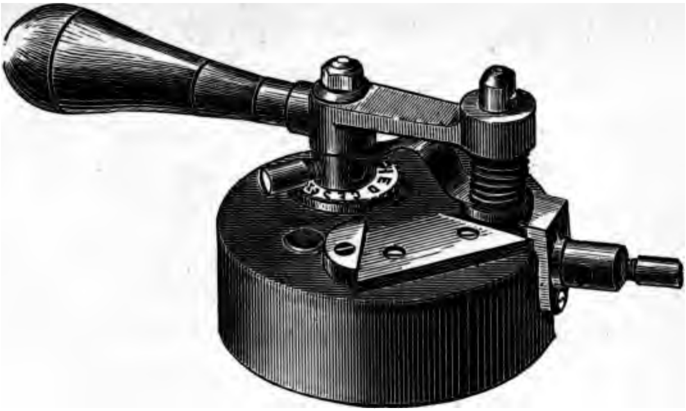


FIG. I.
Hedges' Contact Breaker for currents up to 12 ampères.

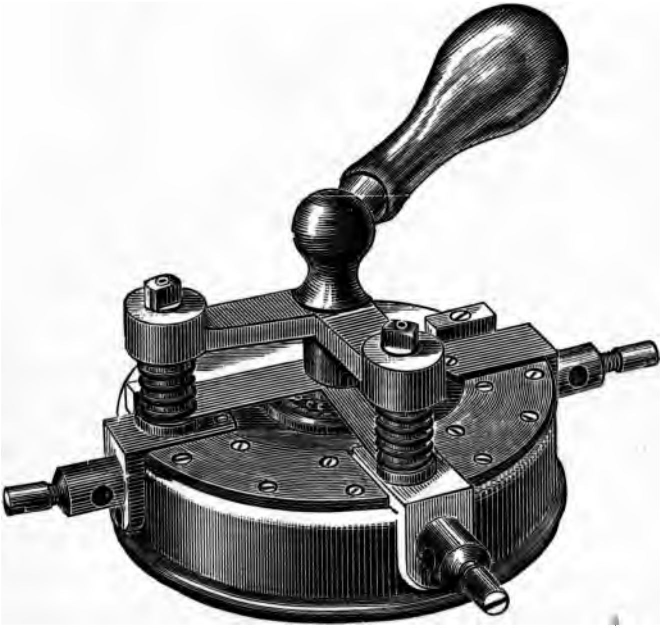
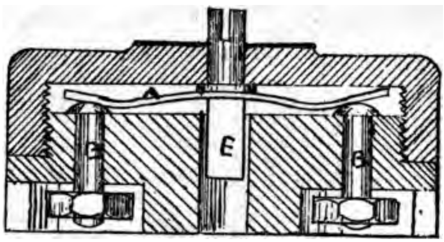
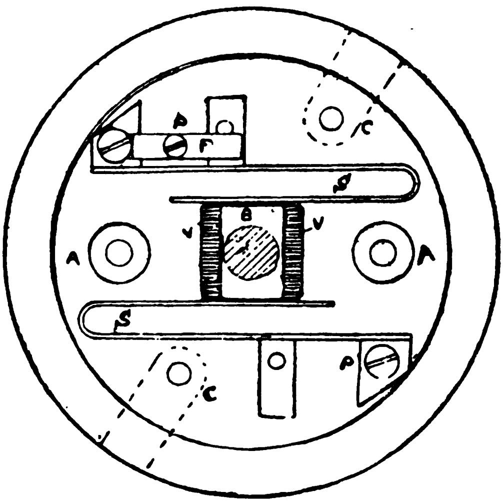


FIG. II.
Hedges' Duplex Contact Breaker of two directions with renewable loose *contact pieces*, which are kept clean by occasionally changing their *position*. For currents above 60 amps. a triplex form should be used.

CONTACT BREAKERS USED FOR INCANDESCENT LIGHTING.

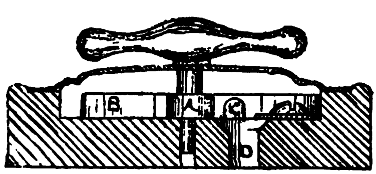


E Central Stem, by turning which the spring A is slid on and off the terminals D D.



SWITCH & CUT OUT, TO SUIT REQUIREMENTS OF THE FIRE RISK COMMITTEE.

C C Holes through which wires are led on one side to the Fusible Safety Plug F, on the other to the Contact Screw P. B Metal Block faced on two sides with insulators V V. S S Flexible Springs which instantly cause contact to be made or broken. The contact cannot be partly made so as to cause an arc.



A Eccentric fixed to the stem and moved on and off the spring B.

sible, which tend to destroy the surfaces in contact, and in a short time destroy the connection.

To obviate this a switch of very good design is manufactured by the Electric Lighting Supply Company in which the sliding piece is circular and movable, so that a new surface is always presented and the contact piece can be renewed easily when worn out. It slides on to a surface of vulcanised fibre, a substance which has high insulating qualities, and withstands heat. Where currents of high electro-motive force are employed it is best to break contact in two places at once, which prevents any chance of an arc being formed at the moment of rupture.

A *cut-out* is always used in connection with a *resistance*, which is best made of a coil of fine iron wire, the length of which must be calculated to allow for the increased resistance due to a rise in temperature. If space is an object a german-silver coil takes up less room, or a series of carbon rods may be arranged in a frame; but the latter have a tendency to disintegrate. The object of a cut-out is to automatically put in an artificial resistance to

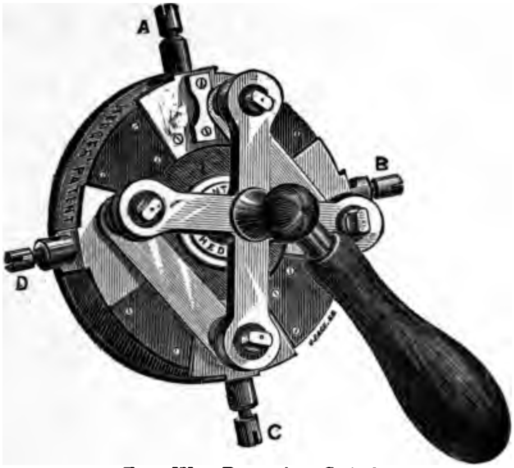
compensate for the extinction of a lamp so that the total resistance in the circuit may remain the same. Iron wire is very suitable, as its resistance is about six times that of copper. In the Brush system this is very ingeniously done by making the current passing through the high resistance coil of the solenoid magnetise a small electro-magnet which pulls up an armature and throws the lamp out of circuit. Some trouble has been given by the copper points becoming soldered together when the cut-out comes into action. The author finds it better to let the contact be made by a platinum point on a metal stud of sufficiently large diameter to conduct away the heat. Care should be taken to prevent the resistance wire of a cut-out touching anything inflammable as it becomes intensely hot.

Division of the Electric Light.

Lighting by Incandescence.

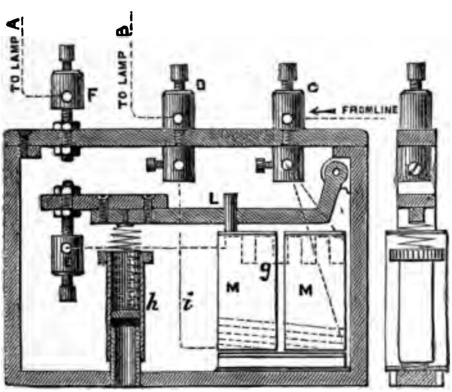
Until a very recent period it was thought practically impossible to divide the electric

pp. 38-39.



Four-Way Reversing Switch.

The current enters lamps at B, passing from the positive terminal A through the contacts of the switch. By sliding the contact which is on A on to B the connection with A is broken and the current enters the line of lamps from the machine by the terminal D.



Cut-Out.

M M Electro-Magnets attracting lever. *h* Spring causing L to be released from M on any accident occurring in the lamp circuit.

current when used to form the voltaic arc so as to furnish several lights of lower power than if the whole current was used to furnish a single light. This difficulty was overcome first by the use of alternating currents of great intensity, and afterwards by having improved regulators working with continuous current.

The lighting of the Thames Embankment by the Jablochkoff candle is an early example of the first plan, and the Brush light at the Liverpool-street Station of the Great Eastern Railway was the first installation here of a number of lights working by a continuous current.

Still strictly speaking, in neither of these is there actual division of the current, nor can there be with the true voltaic arc, which it is impossible to subdivide in the plan adopted with incandescent lights.

Where lights of less intensity than 300 candles are required it is not economical to use the arc system, and recourse must be had to the second application of the electric current —that of *lighting by incandescence.*

If the voltaic arc is not present the light due to the radiation from metal or carbon as it becomes heated by the resistance offered to the

passage of the current is small in comparison with the rays of the true voltaic arc. Incandescence, however, has the advantage when suitably arranged of not involving the renewal of the heated substance. It was thought at first that if the radiating material was metallic, hardly any attention would be required. Platinum was used with success, as well as several other metals, but all of them required an arrangement to prevent their becoming fused by the intense heat.

Edison patented several plans to prevent this occurring, as it was necessary, in order to get the greatest amount of light, to heat the metal almost up to its fusing point; however, in spite of numerous experiments, the something always effectual was not altogether arrived at.

For this reason carbon, which is a very bad conductor, was found to be better than a metal, as it may be heated to an extreme white heat without fear of fusion. The sole inconvenience in the use of carbon consists in the fact that, when highly heated, the carbon combines with the oxygen of the air, and thus becomes gradually consumed.

This was overcome by heating the carbon

in a closed vessel from which the air has been expelled, as in Konn's lamp which worked for some period in Russia, or by inclosing the carbon in nitrogen gas, as in Messrs. Sawyer & Man's process. The carbon used in this last arrangement was hardly larger than a pin, the vapour of nitrogen preventing it being burnt away.

Many experiments have been made by different inventors of arrangements for dividing, and thus utilising, the electric current. The divisibility of the electric light is not, as generally supposed, a new idea. A patent was taken out by King in 1845, in which the inventor especially describes a means of using two or more lights on the same circuit.

Forty years elapsed since Starr took out his first patent for incandescent lighting until the successful plan of fixing the carbon in a vacuum was practically demonstrated almost simultaneously by Swan here and Edison in the United States.

The incandescent systems are much less numerous than those for utilising the voltaic arc, so their classification is far less complex. They may be divided into—1. Incandescent

lamps with combustion; and—2. Lamps of pure incandescence.

To the first kind belong the lamps of Werdermann, Reynier, André, Napoli, Joel, Gülcher, and Hedges' Star lamp. In each of these a carbon rod of small diameter either is pressed up by a weight or falls on to a carbon or metallic electrode, the current being led in such a manner that the extremity of the thin carbon is made excessively hot, and gives out an incandescent light. In the Werdermann, Napoli, Joel, and Gülcher systems the contact is made extremely lightly, so that by reason of the imperfect contact a minute arc is formed which enhances the light.

The arrangement in the Star lamp is somewhat similar to the Reynier; the incandescent carbon, however, is inclosed by a glass globe fixed with an air-tight joint. After the first hour considerable economy in the consumption of carbon is effected by this plan, due to the partial vacuum being formed. If 1 metre length of carbon be used in this form of lamp the light would be maintained for about twelve hours; with a partial vacuum, however, the same lamp will burn nearly seventy hours, the

rate of consumption for the first hour being about six times as much as each hour afterwards. In Gülcher's lamp the carbons are placed above each other, the separation being effected by an electro-magnet pivoted on an axis, one pole pressing on the carbon rod while the other is attracted by means of an iron armature. This action is very sensitive, and with M. Gülcher's system of distribution twelve lamps may be worked together.

Pure incandescence is represented by four systems—Edison, Maxim, Swan, and Lane Fox. The light from this description of lamp is from the heating of a carbon filament due to its high resistance to the passage of the current. This filament is surrounded by an hermetically sealed glass bulb from which all the air has been extracted. The life of the lamp depends greatly as to how carefully this process has been carried on. It is not sufficient only to extract the air when the lamp is cold, but the process must be carried on when the lamp is burning, and the exhaustion must be continuous for some time.

These lamps can be worked either by an alternating or a continuous current machine;

and, unlike those of partial incandescence, require a tension current, while the former work best with a quantity one.

The Edison Lamp.

This invention is generally considered to be the pioneer of this system of illumination. Whether this be so or not the name of the inventor has been for a considerable time associated with lighting by incandescence, although his early experiments were with a lamp containing a metallic substance. As at present manufactured, the lamp consists of a blown glass globe containing a very fine filament made from the fibre of bamboo carbonised. The length is fixed according to the resistance required; for instance, if 125 ohms, the light is found to be equal to 16 candles. Each end of the filament is nipped between a miniature vice composed of platinum connected with the terminals of the lamp. These are fixed in an insulated socket, which also holds the glass bulb. The socket is furnished with a screw which fits into a projection on the bracket or holder, so that the act of screwing in the lamp makes the necessary connection with the con-

Edison Lamp and Contact Tap.

Maxim Lamp.

The estimated cost of an Incandescent Lamp per annum is given by Dr. SIEMENS as 21s. 9½d., including renewals.
A good Argand Burner to produce the same effect would cost 29s.

Swan Lamp, with Spring Contact Holder.

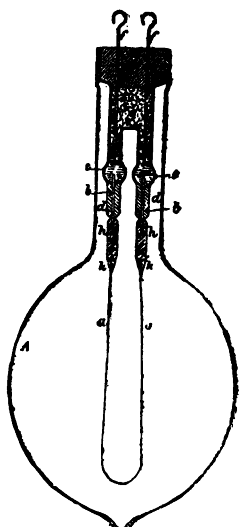


FIG. 8.

Lane Fox Lamp.

a Carbon Filament. *h* Hollow Cylinder of Carbon, uniting Filament to Platinum *b*.

ducting wires. By turning a tap the lamp can be removed without interrupting the passage of the current. The maximum duration of the lamp is stated to be 1200 hours, and the selling price in New York is said not to exceed 2s. 6d. per lamp.

The chief feature of the Edison system is the manner in which the inventor distributes the current from a main generator of his own design, which is always used with this system of lighting, particulars of which will be found to be referred to under the head of machines.

The Swan Lamp.

At first sight this lamp appears to differ very slightly from Edison's, the main point being the way in which the carbon filament is manufactured and applied. The horse-shoe form of the carbon is discarded, and two twists given to the filament so as to augment the lighting area. They are made from cotton threads about four inches long treated with sulphuric acid then carbonised at a high temperature out of contact with air. After this process the carbon acquires great elasticity and can be bent almost double, when released

springing back like steel. The hardening process causes the carbon to acquire less resistance, which at first sight might appear a disadvantage, as the intensity of the light is due to the amount of heat developed. This is found not to be so, as the electro-motive force is diminished, and the harder the carbon is the less it is liable to rupture. Six Swan lamps of the smaller size have in an experiment given a total of 270 candles per horse power expended on them, or at the rate of 42 candles each. The average light per lamp in ordinary work is about 16 to 20 candles, and the lamps have lasted as long as six months. The Swan lamps are joined to the pendants, or holders, by means of a simple arrangement of spring clips. In a lamp intended for mining purposes, and designed by Mr. Crompton, the lamp bulb is placed in a strong exterior glass protected by wires. To allow for blows or jars, which might injure the bulb inside, it is held up by means of a flexible spring against a water tight joint connection. The same kind of lamp may be used for submarine operations.

Swan lamps may be worked by almost any kind of generator. The inventor prefers an

alternating current, as with a continuous one the carbon filament occasionally gives way at the positive connection terminal. Up to the present time the largest installation of electric lighting is successfully accomplished by the lighting of the Savoy Theatre with 1200 Swan lamps.

The Lane Fox Lamp.

This system resembles both those previously described. The horse-shoe form of Edison is adhered to, but the filament instead of being larger at its extremities remains the same size, and is fixed into two little cylinders of plumbago, which are also connected to the platinum wires, each fixed in a glass tube containing mercury, in which dip the connections leading from the exterior of the lamp.

The filament is composed of stalks of grass or of vegetable fibre vulcanised and impregnated with chloride of zinc. To form the vacuum in the lamp the Sprengel pump is not employed, but an improvement of a barometrical air exhauster, which has been used for the production of the vacuum in the well known Geissler's tubes.

Seven lamps are easily worked per horse

power, each having a lighting power equal to 22 candles. The resistance of each lamp measured when cold varies between 75 to 105 ohms, when hot it is about 45 per cent. less. This system is employed for the illumination of the reading-room at the South Kensington Museum, a Brush machine furnishing the current to a number of 20-candle lamps.

The Maxim Lamp.

A sort of gridiron shape is given to the filament, which is much thicker than that used in any of the previously described systems, thus giving more light per lamp, but taking considerably more power. The carbon is made of Bristol board. After being partially carbonised it is submitted to the action of carburetted hydrogen gas, which deposits its carbon over the entire surface closing the pores of the cardboard and giving it sufficient conductibility for the passage of the current. After being fixed in a lamp a vacuum is first produced, and the filament then rendered incandescent; the heat serves to expel the gas self-contained, and therefore surrounds it in an atmosphere of carburetting gas, which the

inventor claims has a tendency to recarbonise any weak points.

The connections through the glass of the bulb are made by means of a blue enamel, which seems to act very well.

The resistance of these lamps is said to be from 40 to 60 ohms, and their lighting effect is given at 20 to 50 candles, and can be worked to a much higher power. Some experiments made at the Paris Exhibition were with lamps working up to 900 candles per horse power.

The great objection to illumination by incandescence is its susceptibility to any irregularity in the motor; in fact, it is often the practice to put an incandescent lamp up in an engine room as a tell-tale where arc lights are being worked out of sight, any irregularity of the regulator being intensified in the incandescent one.

Current Strength Regulators.

With a large number of incandescent lamps an apparatus is necessary to reduce the amount of current given out by the machine proportionally to the number of lamps turned out,

and thus save the power which would otherwise be expended in heating up resistances. Though each inventor has a plan of his own, this can hardly be said to have been accomplished yet. Edison proposes to use an apparatus at the central generating station which either automatically or by hand reduces the electro-motive force of the current in circuit to 110 volts, the working strength of current; in the same manner as the gas in the mains is kept at a certain number of inches' pressure of water.

In the Lane Fox system the same effect is produced by causing an electro-magnet to work a vibrating arm, similar to that of an electric bell, but which is so arranged that by its action a resistance is substituted equivalent to the number of lights turned out.

Maxim's regulator consists of a vibrating arm thrown either in or out of gear by electro-magnets actuated by the current and fixed on the top of the dynamo-machine in such a manner that the movement of the arm causes a corresponding movement of the brushes on the commutator.

Unfortunately this plan is open to the grave objection that as the brushes are moved

towards the neutral point of the commutator the tendency to give off sparks increases.

MACHINES OR GENERATORS.

In a condensed treatise it is impossible to go fully into the subject of the merits of the various machines for producing the necessary amount of electricity or review the history of the earlier machines.

For all practical purposes it is sufficient to classify the generators of electrical energy as used for lighting purposes and for the transmission of power into three heads, which are placed according to priority of use:— I. Magneto-electric. II. Dynamo-electric with separate exciter. III. Dynamo-electric (*i.e.*, pure dynamo).

I. Magneto-electric machines represent the first practical type of generators of the Holmes and Alliance type. Although many of these are still at work the only one of the system manufactured at the present time is De Meriten's in France and Dr. Hopkinson's here.

The first is an improvement on the old Alliance pattern, which has been used at the Cape de la Hève lighthouse since 1863. The De Meriten's machine has been adopted for the illumination of the French lighthouses, but the size and expense of this class of generators prevent their being generally adopted.

To Class II. belong the Lontin, Wild, Duplex-Gramme, and Siemens alternating current machines. They all admit of several currents being taken from the machines, and each have a separate exciting machine for generating the current round their field magnets. The revolving armature in these machines has a very high velocity at its circumference, so as to generate a current of much higher tension than that from the exciter. The current is taken as generated without the intervention of a commutator, and is alternating in direction.

Sometimes the exciting machine is fixed on the same shaft as the generator, when the combination is known as an '*auto-exciter*.'

The reason for using the exciter is;—that when an electro-magnet is produced by a current from a separate machine the magnetic field or

attractive power of this magnet is far more powerful than if the magnetism had been induced only by the revolution of a coil of wire in front of it. This plan was taken advantage of some time ago, and is always used wherever high tension alternating currents are required.

The Duplex-Gramme machine is very largely employed for the Jablochkoff and Jamin systems, and now that the manufacture is improved, it is thoroughly serviceable and very compact; the exciting machine is self-contained. This combination has stood the test of practical work without change of design since its first construction. The Siemens alternating current machine is, however, simpler, and cheaper to make. With the exception of the Van Alteneck armature of the exciter, which is, in this case, a separate machine, the general principles of both these alternating current systems are almost the same.

An important improvement in the Siemens machine is the omission of the iron cores from the revolving coils. The heating effect of the cores caused by the incessant reversing of their polarity is thereby avoided.

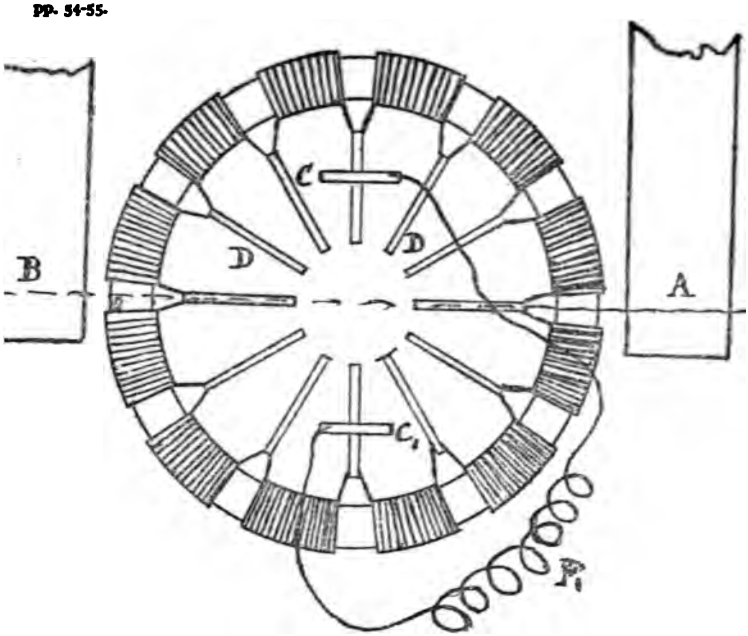
The Lontin has a family likeness to both the preceding machines, but differs in the arrangement of the coils in the distributing machine, which are placed in a diagonal direction. The coils also are so coupled that by means of a special form of circuit changer the current from the machine can be divided at will into separate circuits.

III. Dynamo-electric machines, called for short *dynamos:* they are employed usually without a separate exciter, but this can also be used if required.

The principal systems are the Gramme, Siemens, Bürgin, Brush, Edison, Maxim, Weston, and Schuckert; all of which give a continuous current.

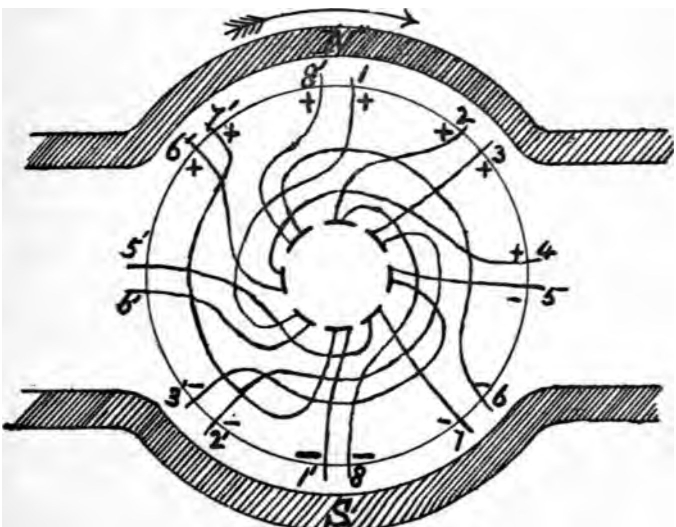
To describe each machine in detail would take too much space, so a short account of the peculiarities of each system will therefore only be given.

The Gramme ring or bobbin is the foundation of the success of this system, and is the same in all the varied types constructed. It consists of a coil of soft iron wire round which a series of distinct bobbins of insulated wire are wound side by side and connected to copper L shaped



Skeleton Diagram of Coils in Gramme Machine.

A B Poles of Electro-Magnets. C C Brushes pressing on the Commutator. D Ends of Commutator Plates connected, the Coils wound on the ring. A Resistance in Exterior Circuit.



Skeleton Diagram of Siemens' Machine,

***Showing method of* connecting Coils to Segments of Commutator.**

plates, the lower ends of which are prolonged and insulated from each other so as to form a commutator (*vide* page 7).

This ring when complete is fixed on to a shaft by means of a wooden hub and caused to rotate between the poles of two electro-magnets, and these are furnished with suitable pieces which embrace the ring without touching it.

The currents induced by the revolution of the bobbin in front of the electro-magnets are picked up by the brushes which lightly press on the commutator, and are connected to the positive and negative terminals.

The three Gramme machines of the **A** type tested at Glasgow in 1880 differed slightly in resistance from each other; that by Emmerson & Murgatroyd, the makers for the English patentees, had a resistance, brush to brush, of 0·350 ohms, and from terminal to terminal of 0·997 ohms. With 2·89 horse power a current of 29·5 webers was maintained through a resistance of 1·528 ohms at 993 revolutions per minute.

The action of the Siemens machine is precisely the same, but the formation of the revolving bobbin is different.

Instead of the iron wire ring a circular iron armature of greater length is used, which is cut away so that the wire is wound round it parallel to its length. The electro-magnets instead of being each in a piece consist of several bars which encircle the bobbin.

No trials were made at Glasgow with the Siemens machine, but Dr. Hopkinson has carried out some extensive experiments with these, from which it appears that both for efficiency and practical results there is little difference from the Gramme.

All the later inventors seem to have rung the changes on these two systems, which, as originally designed, were intended for single powerful lights from 5000 to 10,000 candle power, and in order to maintain a second light it was necessary to run the machine at an excessive speed.

Machines for maintaining more than one arc may be called *multiple light machines*, and these are the kind most adapted for general use. Gramme accomplishes this in a most efficient manner with his auto-excited continuous current type.

He reverts to the plan first used by Ladd,

and has a small machine solely for the magnets of the larger one in which it is contained. Ten arcs in lamps of the Gramme pattern can be maintained from this machine.

For high electro-motive force another type of Gramme machine has been designed by Mr. Radcliffe Ward, and is largely employed in this country. It resembles the original pattern with a very much larger bobbin; also the field magnets are flat instead of being circular.

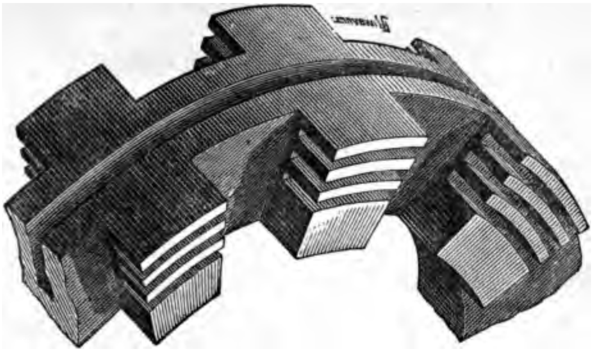
It is usually excited by a smaller size separate machine, when from four to six arc lights of 4000 nominal candle power each can be easily maintained. For six lights 12 horse power is required, the machine making 1000 revolutions per minute.

Siemens has no special continuous current machine of this type. Where several arc lights are required in series of high-tension currents, such as are used for the Swan lights, the ordinary alternating machine is employed.

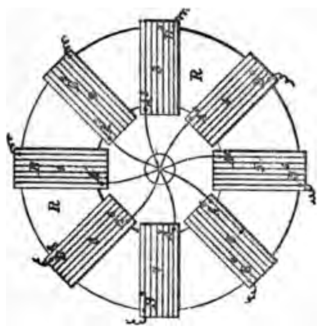
For currents of very high electro-motive force the invention of Mr. Brush is the only one in successful use.

This machine differs from the Gramme and the Siemens machines in several points. It is

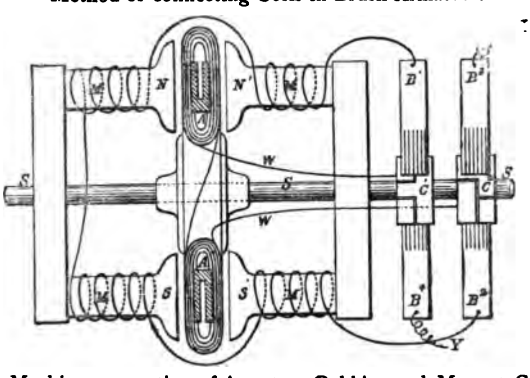
specially designed to generate and maintain a direct-acting current through a great external resistance. The ordinary practice, as with alternating currents, is to employ two machines —a small one known as the exciter or primary machine and a larger one in which the current created by the primary machine is distributed in such a manner as to produce the amount of tension required. These currents then become alternating in direction. In the Brush system the primary exciting machine is done away with, and an ordinary direct-acting current of high tension is produced without any complication of coils. This is effected principally by the arrangement of the field magnets and annular armature, which consists of a wheel of large diameter nicked out at interval to contain the coils. The inventor claims that although the resistance of the armature conductor, measured through the brushes on the commutator, does not exceed 4 ohms, when the armature is rotated at the normal speed of seven hundred and fifty revolutions per minute the electromotive force developed in its conductor is sufficient to maintain a normal volume of current through an external resistance of



Part of Cast-iron Ring of Brush Armature.



Method of connecting Coils in Brush Armature.



Brush Machine connection of Armature Bobbins and Magnet Coils in one position of the Armature revolution.

The current induced in A A^1 is transmitted by wires W W passing through the shaft S to the commutator C^1, whence it is collected by the brushes B^1 and B^4 at the same time the other portions of the commutators are in contact with the brushes B^2 and B^3. X and Y are the terminals of the external circuit, and to the brushes B^1 and B^2 are connected the *two ends of the* magnetic field wire.

80 ohms. The current thus operates from sixteen to eighteen lights placed in circuit, giving to each an arc of about $1\frac{1}{2}$ millimetres. The division of the electric current is thus much more favourably accomplished than is generally supposed. The light given out by each lamp does not appear to the ordinary observer to be greatly augmented or diminished by altering the number of lights in circuit to a certain extent, although doubtless there is a loss of economy in driving power when only a few lights are used.

The great perfection arrived at in this system was shown by the lighting of the Paris Opera House by thirty-eight Brush lamps placed in series taking a current from a 40-light machine connected by a cable three and a half miles in length.

The ordinary Brush lights are said to be about 1800 nominal candle power.

The Weston machine, although similar in some respects to those previously described, differs greatly in details.

The revolving armature resembles Siemens, but instead of being solid is built up of several discs threaded on a spindle so as to allow an

air space between each: these and other peculiarities are for improving the ventilation and prevention of heating. With its specially constructed lamp ten lights may be maintained in series.

The Maxim machine is in physical principle a combination of the Gramme and Siemens. A modification of the Gramme armature is worked in a Siemens magnetic field, a smaller machine being used to excite the currents. It is employed chiefly to generate the currents for the Maxim incandescent lights, which have been previously described.

Edison has succeeded in building the largest dynamo machine yet seen. Some idea of its colossal size may be gathered from the fact that the whole apparatus weighs no less than 17 tons, the rotating armature weighing 2½ tons alone.

Long cylindrical electro-magnets are used in the Edison system, the coils of which form a shunt or derived circuit of the machine. The armature is the most interesting part of the apparatus. In the larger size no wire is used, the inductive portion being built up of a number of copper bars or prisms fixed longitu-

dinally round the circumference of the cylindrical core and insulated from each other. At each end of the armature are strung a number of flat copper washers to which at its edge is connected one of the induction bars, which is also connected in a similar manner at the other end. The general appearance is like that of Siemens only the awkward complication of wires at the ends is avoided.

The large machine, which is the type it is proposed to establish in central generating stations, is intended to work 2000 half-lights of about eight candle power each, or 1000 whole lights of sixteen candle power.

The conductors for this machine are solid copper rods imbedded in a resinous material inclosed in gas tubing, the screwing together of which forms an electrical joint in the conductor, suitable arrangements being made to allow for expansion by heat.

The Schuckert machine so nearly resembles the Brush that, with the exception of pointing out that the design is well adapted for manufacturing cheaply, it is a question of priority of invention.

The most workmanlike machine in practical

use is decidedly that invented by M. Bürgin, of Switzerland, especially in its modified form in which it is known as the 'Franklin.' To get a high electro-motive force a high surface velocity of the coils of the armature is necessary, but the wire in the ordinary Gramme ring does not admit of this on account of the coils being closely confined and apt to heat. In the Bürgin machine the coils are each wound on individual rings instead of the separate rings of the Gramme machine; also instead of the solid circular hoop of the Gramme each core is an hexagonal frame of wire built up into a bar. This renders the winding of the ring very simple and reduces the number of layers, but with the few coils on a ring it is necessary to increase the number of rings so that with the three-light machine eight rings are arranged side by side, each being a little in advance of its neighbour.

In the event of a ring being damaged it can be removed and rewound without interfering with the winding of the others.

The eight rings form the armature, the resistance of which is 1·6 ohms, which, when revolved at 1600 revolutions per minute, gives an electro-motive force up to 206 volts.

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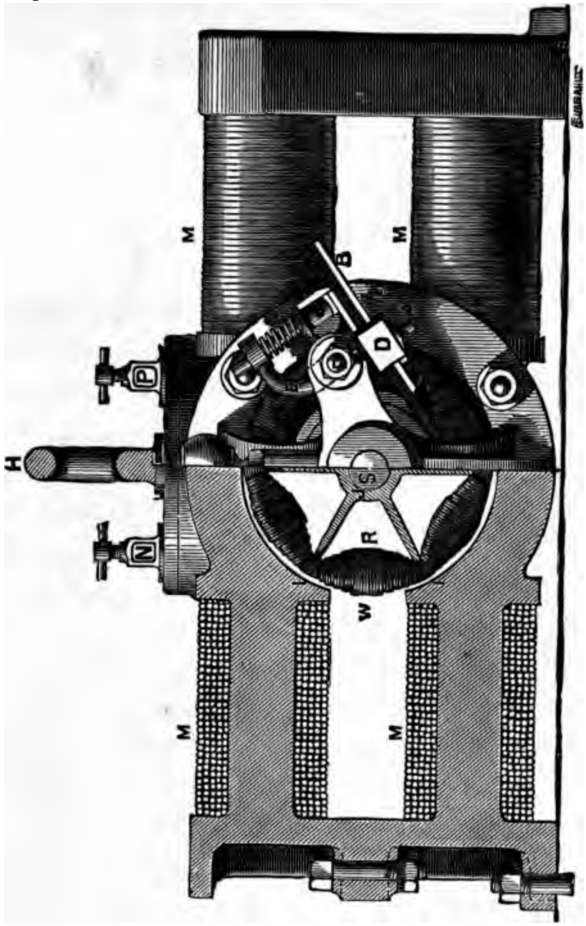
The Bürgin Machine.



M Field Magnets. W Revolving Armature. B Collecting Brush. G Spring Apparatus for adjusting pressure of Brush.

Commutator and Rings of the Bürgin Machine.

With this machine three lights of 3000 candle power each can be obtained at 1450 revolutions with $4\frac{1}{2}$ horse power, and by increasing the number of rings on the shaft and lengthening the electro-magnets four or more lights can be worked.

The question now arises as to which is the most economical system to employ for lighting purposes, the single or the multiple light? Both lights have their advantages, no rule can be laid down, but the exigences of the case must govern the choice.

As previously stated, the great drawback of having numerous lights on one circuit is, that almost the same amount of power is required to drive the dynamo machine whether all the lights are employed or only a few. Thus, for example, in the Brush machine an amount of 13·78 HP. is required to produce sixteen lights; suppose ten of these are turned out, in each of the lamps extinguished the current is doing an equivalent of useless work, passing through a resistance coil attached to the lamp, which is necessary to insure the uniform working of the series of lights. In the single-light system directly a lamp is put

out the circuit becomes 'open,' and only the power absorbed by the friction of the machine is required to drive it. The great gain of the multiple over the single light is in the cost of conductors to lead the electricity from the machines to the lamps; and under certain circumstances, such as the lighting of railway stations, public parks, and factories, where a number of lights are required, it is certainly the best. For general purposes, especially where the electric light is the only source of illumination, it is better to employ several machines, each actuating four or five lights. In some cases, such as the lighting of engineers' shops and for contractors' work, the dynamo machine can be placed close to where the light is required, thus saving the cost of long conductors.

In selecting an electric generator the choice should fall upon one which, occupying little space and requiring but a moderate degree of driving power, is reasonable in cost and offers at the same time every possible guarantee for durability and steadiness of action. To rest the choice solely on the bulk and driving power would be to commit a great error, for in some

cases the power costs nothing and the reduction in size is of little moment.

The tendency to spark at the points where the brushes press on the commutator is observable more or less with all machines. As long as no erosive action takes place very little wear will be found from this cause, especially if the commutator itself is kept well cleaned and polished. An oily rag pressed against the metal while the armature is revolving will remove the particles of copper from the commutator, when a final polish should be given with flower of emery or crocus paper.

It is found that if two machines are coupled up in parallel circuit there is a gain of about 20 per cent. in the light produced. This has been taken advantage of by M. Gravier, who exhibited at the late Paris Exhibition a battery composed of six Gramme machines coupled together and giving a continuous current. The electro-motive force of this battery was said to be equal to 86 volts, with a current of 180 ampères; so that it would be capable of lighting 30 arc lamps. The actual duty when working at the exhibition was equivalent to a current of 120·04 ampères.

POWER REQUIRED, AND MOTORS.

Steam, Gas, Petroleum, and Hydraulic Engines.

Dynamo and magneto machines are simply appliances for converting mechanical energy into electrical energy. The heat developed in the boiler by the combustion of the fuel is carried by the steam to the engine, which converts it into mechanical energy; this, by means of the dynamo machine, is again converted into electric force.

The power required to produce the electric light was formerly taken as one horse power per 800 to 1000 standard candles. Improvements have however increased this, that it is possible to get over 1500 candles per indicated horse power with the voltaic arc, or about 200 candles of the incandescent light is employed.

In making a calculation of the power required to drive a dynamo-electric machine 25 to 35 per cent. must be added to the normal power in order to overcome the resistance of starting the machine. To secure the uniform working of the machine, which is absolutely necessary for the production of a steady light, a good motor is required.

1000 candles in arc lighting per horse power, and 160 for incandescent, is a fair result in practical work.

A strongly made portable engine is the kind most in use in France. Portable engines are very good for temporary work, but have the disadvantage of taking up much room. The boiler also requires considerable attention and cleaning to prevent the tubes being incrusted.

Whatever engine is used, it is always advisable to have a thoroughly efficient governor. The best kind for this purpose is one working direct on to the slide or expansion valve, altering the amount of steam used in each stroke.

Where this is not used the governor should have an adjusting screw so arranged that it will perfectly control the engine at different speeds, varying according to the number of lights to be worked.

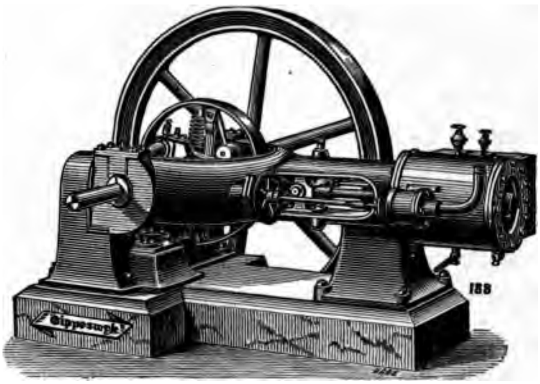
As an aid to regularity in working, the flywheel of the engine should be heavier than usual and counterbalanced on the opposite side to the crank. If a countershaft is used the riggers or pulleys on it should have heavy rims and be carefully balanced so that their speed is regular. So sensitive are the incandescent lights that a badly laced belt will cause a fluctuation as it passes over the pulley of the

dynamo. Belts should be fastened with butt or turned-up ends, and not lapped.

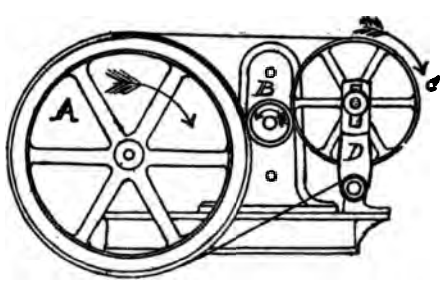
For large installations a condensing engine should be employed, the horizontal Corliss type being especially suitable, and is capable of producing a horse power with $1\frac{1}{2}$ lbs. of coal, but usually $2\frac{1}{2}$ to 3 lbs. is considered good with this class of engine, and 6 lbs. with the ordinary type. Up to 15 horse power a self-contained horizontal works economically; it must, however, be well made, with ample bearing surfaces, and have all parts interchangeable, so that in the case of a breakdown the faulty piece can be taken out and a new one substituted out of stock.

Several makers have made special designs for electric engines; among these the author finds the Gippeswyk pattern of Messrs. E. R. & F. Turner to fulfil all the requirements mentioned, and at the same time to be very moderate in price. These engines are also combined with a boiler and mounted on a frame resting on four wheels, which also takes the dynamo machine. The driving arrangement is novel, and enables the whole plant to be combined into a very small space. For a portable elec-

pp. 68-69.



Gippeswyk Engine with Automatic Governor.



Hedges' Gearing arranged with Gramme Machine.

A Fly Wheel. B Pulley of Dynamo. D Idle Wheel, which can be lowered so as to tighten the belt C.

tric lighting tackle the high speed at which dynamo machines are worked renders it impossible to connect the engine direct if the ordinary type is employed. With gearing great annoyance is experienced in consequence of the noise, while the ordinary smooth running strap takes up too much length. To obviate this the generator is driven partly by friction and partly by a strap. This will readily be understood by imagining the driven pulley to be in the centre of two others, and in frictional contact; that on the left side being the flywheel of the engine, and that on the right an idle wheel revolving on a shaft.

By encircling the two outside wheels by means of a strap the disadvantage of driving by friction alone is removed, and the pressure on the bearing of the dynamo is equalised. This system of driving has given great satisfaction for use on board ship, where the space is, as a rule, very limited, and the noise of a direct acting engine objectionable.

Boilers.

For large powers where space is no object an elephant or Cornish boiler set in brickwork

needs the least repairs, but such boilers should always be in duplicate.

Where surplus available power is to be had from an engine already at work, to utilise this power would be the most economical plan. Care must be taken that it never falls below that necessary to drive the dynamo or magneto machine, or the light will either become unsteady or perhaps be extinguished.

Gas engines have been frequently successfully used. They are not to be recommended unless it is impossible to have any other form of motor. Besides being more expensive in first cost than a steam engine, they are, so to speak, a fixed power, while the power of a steam engine can always be slightly increased by a small addition to the working pressure. In gas engines the repairs are obliged to be effected by workmen who understand their construction, who are not always easy to get.

Where gas is used great care should be taken to have the supply pipes sufficiently large and direct from the main; the gas bag should be very large, as often during the day the pressure in the mains is so reduced that the engine cannot get enough: this often happens

when a fog comes on, and a large amount of gas is required suddenly.

The petroleum engine is very largely used in America, and will doubtless before long be popular here. The trials at the Philadelphia Exhibition proved it to be more economical than a gas engine, half a gallon of petroleum producing nearly five horse power per hour. A gas engine required 190 cubic feet to develop the same amount of power in the time.

Hot air engines have been employed for driving the electric light machines in light-houses, and are said to work very economically. Water is the most advantageous source of power, but unfortunately it is not always obtainable. Beyond the first cost of the conductor distance is no object, which was ably pointed out by Sir William Thomson at the meeting of the British Association by illustrating the force of Niagara as capable of developing 21,000 horse power 300 miles from the fall.

For low heads a water wheel of the Poncelet form is the best, but with a considerable fall a turbine may be used more advantageously. In many instances the pressure in the mains is

sufficient to work a water engine, which may be arranged to give a duty of from 70 to 80 per cent. of the theoretical power.

Where a large quantity of water is employed the power may often be obtained for nothing by making the engine exhaust into a tank.

The author has put this plan into practical operation, and has proposed it for the lighting of the Euston Railway Station, where the water pressure is 70 lbs. on the square inch, a very large quantity being used for supplying the locomotives, which could be drawn from a tank fixed at a low level.

In many instances surplus water power is to be found in the neighbourhood of large towns, and this can be utilised for street lighting: the saving in the motor will often be found to turn the scale as regards cost in the favour of electricity against its rival gas. The town of Godalming has been lit in this way for some considerable time, using the power of a water wheel supplemented by that of a steam engine when the river is low.

A complete apparatus for the manufacture of a cheap kind of gas has been invented by Mr. Dowson. It consists of a generator con-

taining a fire through which steam is blown together with a certain proportion of air, the steam becoming decomposed and an inflammable gas of low illuminating power being the result, which can be used for driving a gas engine. It is claimed by the inventor that as regards cost it is 50 per cent. cheaper than coal gas at 3s. per 1000 cubic feet.

Application of the Electric Light.

Lanterns, Globes, Colour of the Light.

Much has been said respecting electricity replacing gas as an illuminant. The fields of each lie apart, and doubtless it is not everywhere that the electric light can be introduced to advantage.

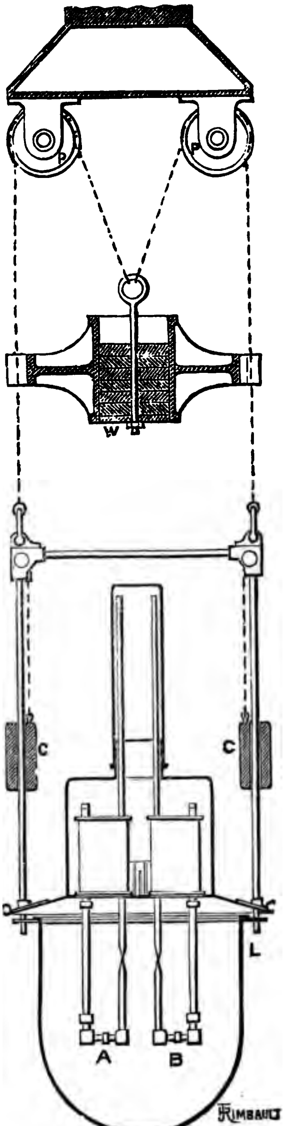
The electric light is, of necessity, very powerful; it becomes then a question how to use it in the most advantageous manner. The objection raised against the light, if applied without a shade, is its great intensity, which renders it, not only too powerful for lighting purposes, but also, by contrast with the ordinary

amount of light given out by gas, produces an effect which is annoying to the eyes.

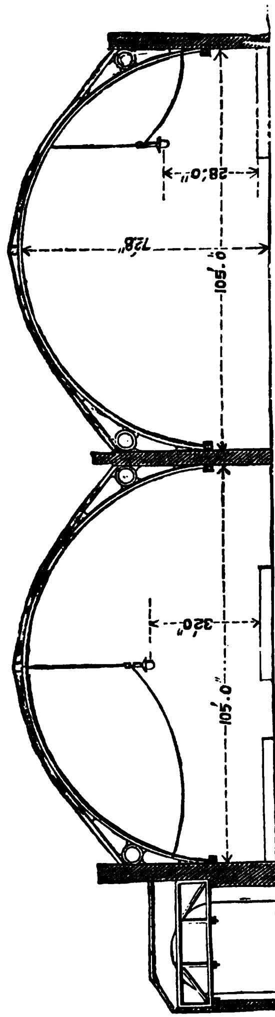
In very few instances can a naked light be employed; in the first place the arc is easily blown out by the wind, and in the second without some means of dispersing the rays the shadows are much too intense.

It is therefore nearly always necessary to use a *lantern*, which should be constructed with a view to great strength, the different parts being fastened together without solder, which is apt to melt by the heat: this in powerful lights is so great that the glass should not approach within ten inches of the arc. A lantern should always be insulated from the lamp, and due regard must also be paid to ventilation, otherwise the explosive gas carbonic oxide may be formed.

The best way to sling the lantern containing the electric lamp is to arrange suitable counterweights and fix a short line to the base of the lantern. This will serve either to pull down by or check the upward ascent. Where the lights are displayed from the tops of high posts it is necessary to have a winch, either hauling direct by a chain or on to the double con-



Crompton Double Lamp in Lantern
with counterweights.



Electric Lighting of King's Cross Station. Arrangement of Lamps.

ductors, which are looped up so that the strain on them is taken by a sliding pulley and chain which is connected to the winch. The plan of making contact when the lamp is pulled up to its required position by touching a suitable fixed stop has been tried, but is not to be recommended.

The form of reflector varies according to the area required to be illuminated. Where a concentrated light is required the crater in the upper or positive carbon is sufficient in itself.

The author has used white enamelled iron reflectors of slightly conical shape for the large beacon lights, each of 4000 candle power, in the Liverpool docks. These give very good results, the white enamel being far better and less expensive than burnished metal or looking-glass.

For public works and contractors' use a single electric focus sufficiently elevated would admit of work being carried out at a radius of 300 feet, and at a greater distance if the beam is converged and again spread by a distant second reflector. In factories, picture galleries, &c., the use of glass shades can often be avoided by causing the rays of light to be thrown up-

wards by means of a reflector. They are then dispersed downwards either by another suitable reflector or by the whitened ceiling.

For outdoor purposes the height at which the lights can be most advantageously fixed must be governed by circumstances. It is very useful to have a rough standard of illumination.

No. 1; may be such as a well lit room.

No. 2; that a newspaper can be read with comfort of the entire area.

No. 3; the light of a very clear autumnal moon, by which any outdoor work, such as dock work, excavating, or levelling, can be carried on with ease.

The following table shows approximately the relative area lighted to the different standards with the same Gramme machine of 4000 candle nominal power, and taking $2\frac{3}{4}$ horse power to work:—

Gramme Machine.	Height of Lamps above ground line.	Standard of Illumination.	Area illuminated in Square yards.
A type	16 feet	1st.	320
"	18 feet	1st.	530
"	20 feet	2nd.	1100
"	43 feet	2nd.	2000
"	75 feet	3rd.	18,000
"	40 feet	3rd.	9000

The number of lights to illuminate a given covered-in space is greatly dependent on the height at which the lamps can be suspended, and the position of columns or angles likely to produce shadows. It is, therefore, often better to use a number of smaller lights than a few large ones, without the latter can be fixed sufficiently high.

Workshops, foundries, &c., are comparatively easy to light, but with interiors, like concert rooms, theatres, or reading-rooms, the question of *colour* is one of great moment.

Colour of the Electric Light.

It may be recalled to mind that one of the principal recommendations of the electric light was its pure whiteness as compared with the yellow of gas. The colour unfortunately turns out to be one of the greatest objections against the general use of the light from the voltaic arc for interiors. It is now well known that this form of light is composed of rays of two colours—those from the heated carbons being white while those from the arc itself are blue. For instance, a powerful current with a short arc gives a very white light, mainly proceeding

from the heated crater of the positive carbon; on the other hand, a current of less quantity and greater intensity, such as is used when a number of lights have to be maintained, gives a much bluer effect. The white light ought to be considered the emblem of all that is pure and beautiful, but as our eyes for generations have been educated to the yellow of gas and oil, we admire, but do not take to the innovation. Besides, more often than not, a blue effect is produced, which gives a smoky appearance to a room so lighted, and a general appearance of having 'too thin' a light.

It appears after all the only plan is either to always employ incandescent lights or to tone down the rays from the arc to the colour of the much abused gas, and by this means the two modes of lighting may be advantageously worked together. The ordinary yellow globes do not answer, as the glass is tinted with chloride of silver, which is affected by the intense light; the aniline dyes give good results, but lose their colouring effect in a short time by the bleaching action of the arc.

Various coloured globes have been tried in the picture galleries at the South Kensington

Museum: the best result was found to be with a yellow colouring matter of an alkaline nature precipitated on the glass in a crystalline form. The dispersion of the light was very good, and the effect of the light in the gallery could not be distinguished from that produced by the gas.

A certain loss of light is occasioned by any colouring matter as well as by the partially opaque shades now in use.

The light lost is estimated for—

Plain Glass Shades	10 per cent.
Ground	30 „
Thick Opal	60 „
Thin ditto	40 „
Coloured Globe (South Kensington Pattern)	40 „

Where it is necessary to obscure glass for temporary purposes an imitation frosting may be produced by brushing it over with a hot solution of Epsom salts.

The incandescent system, which may be taken as the representative form of electric light, is the only kind which can ever be introduced into private houses or compete with the small distributed gas lights. It has none of the

objections just mentioned as regards colour; on the other hand it is ten times as costly as the arc lighting, and can never compete with the latter which, with even 50 per cent. loss of light to secure the desired colour, is considerably cheaper than gas.

With arc lights inclosed in suitably coloured globes the sun burner now used in our large lecture rooms and theatres could be done away with. In some cases a luminous ceiling might be employed. This is simply a screen of glass, of flat or curved form, above which the electric lamps are fixed, and is similar to the plan adopted for the gas lighting at the House of Commons. By making the screen of two plates of glass and inserting the colouring material between the latter would not be affected by dirt or damp, and the light itself would be well dispersed. In theatres objections have been raised as to the bad acoustic properties of this kind of ceiling; the sun-burner, however, is open to the same defect, as a current of air sets directly to it from the stage, and necessarily carries some of the sound in that direction.

Supply of Electricity.

Before incandescent lighting can be gene-ally adopted it must be laid on like gas. Both Edison and Lane Fox have arrangements for distribution; the former especially has so far perfected his system that a large number of houses in New York are now having the necessary connections made to the electric mains. The amount of current used will be measured by an ingenious weber meter registering in the same manner as the common gas meters.

The first cost of laying down such a system is great, and it is rather doubtful whether the public would at present wish to encourage another monopoly. Copper would have to be used for the main conductor, the increase in the cost and weight of which varies as the square of the distance. This means that if instead of going one mile it was desired to go two it would be necessary to double the area of the first conductor through the length of two miles, and in that case there would be a wire of twice the length and twice the area, therefore four times the weight and four times the cost.

Having doubled the area more electricity can be passed through the conductor, so that double the number of lights could be worked through the lengthened conductor.

The electric conductor does not resist the motion of electricity through it in the same manner as a pipe resists the flow of a liquid. The resistance is only increased by a rise of temperature in the conductor, which rise is kept down by the dissipation of heat from the larger surface.

As a set-off against the first cost, if a conductor of suitable area be laid down the streets when not employed for lighting purposes it could be used for transmission of power.

Sir William Thomson points out in his paper read before the British Association that the gauge to be chosen for transmitting a current depends solely on the strength of the current to be used, supposing the cost of the metal and of a unit of energy to be first determined.

By some interesting calculations he finds that the sectional area of a conducting wire ought to be about a fiftieth of the strength of the current in webers. Thus for a powerful

arc light current of 21 webers the sectional area of the lead should be ·4 of a square centimetre; therefore if round its diameter should be ·71 of a centimetre. In practice a very much larger area conductor would be used, but in the case of a very long line, and using water power, it would not be impracticable to follow this rule. The electric light is already supplied for streets in many of the American cities much in the same way as gas, and at the same cost, which is, however, higher than in this country. The Brush arc light is generally employed in some cases by having powerful lights on the top of high poles or by utilising some central tower as a light centre and suspending lamps from it in various positions. The parallel wide streets in American cities favour this mode of illumination. In the City it was not found to answer from the fact that the lamp was much too high for the area to be lighted. The highest of these towers is that erected in Monumental Park, Cleveland, Ohio. It is 250 feet in height, 3 feet diameter at base, 8 in. at top, and is surmounted with five lights of 4000 candle power each.

Secondary Batteries—Fauré's Accumulators.

Secondary batteries must play a very important part in the electric lighting of the future. By their use it is possible to store up a charge of electrical energy which may be produced by an ordinary engine working a dynamo even at an irregular speed during the day. They may be compared to a Leyden jar, only instead of discharging themselves suddenly when contact is made the current flows regularly until the battery is exhausted. Faure's battery has acquired considerable notoriety, although it is directly derived from the Planté's cell, which has been before the public for a considerable time. The electrodes are of lead plunged in water acidulated with sulphuric acid. In Planté's battery the production is limited by the thickness of the lead. M. Faure gives to his couples an almost unlimited power of accumulation by covering them with a layer of spongy lead, retained in the following manner: The two plates are first coated with red lead or other insoluble oxide, then covered with a portion of felt fixed with lead rivets. They are then traversed by an electric current which brings the

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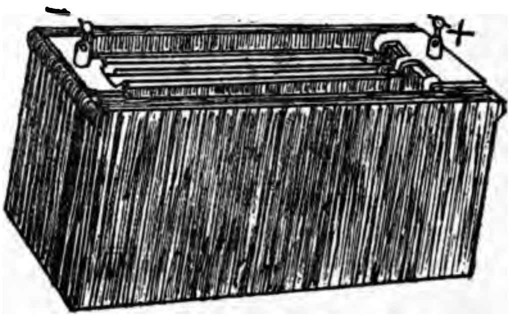
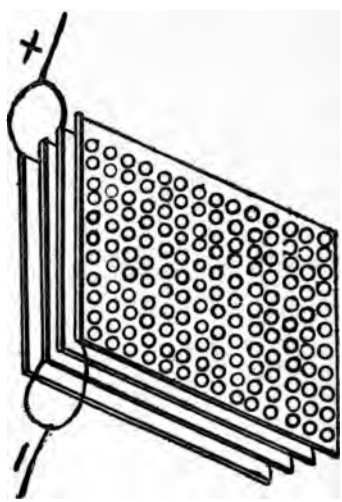
SECONDARY BATTERIES.



Faure Battery.

Planté's Original Battery.



The Perforated Lead Plates of Sellon & Volckmar's Accumulator.

minium or red lead into the state of peroxide on the positive electrode and reduced lead on the negative. On discharge, which is accomplished by connecting the battery to the lamp, the reduced lead oxidises, and the peroxide is reduced, until the couple becomes inert, when it can be recharged.

However simple this operation may appear, there are three great objections at present to secondary batteries: I. The time taken to charge them; II. Their great weight; and III. The necessity of having at least 38 cells to obtain sufficient electro-motive force to work a single incandescent lamp, although the same battery would work a number.

The first drawback will probably be improved by using a current of high tension to charge the cells quickly, and when this is arrived at there will be no objection to such a current being laid on from house to house and turned on to the batteries at certain intervals in the same manner as a turncock puts on the water. Secondary batteries are also known as *accumulators*. This is an erroneous term, as they cannot be said to accumulate power, which is fixed and limited by their internal

construction, so that no amount of overcharging will increase the current.

Choice of a System.

The public are inclined to run in grooves in this matter, and to think that an *electric light* can only be produced by the certain special system which is for the moment most talked about. Dynamo machines compare so closely with each other as regard efficiency—both the Gramme and Siemens are each shown to utilise nearly 90 per cent. of the power applied to them—that to ascertain which is the best machine it is necessary to look to other points beyond the theoretical efficiency.

The makers names are, as a rule, a sufficient guarantee; but as electric lighting becomes more general second-hand and obsolete patterns of machines will be in the market. The earlier types of Gramme and Siemens machines can be recognised by the few divisions in the commutator, which caused a considerable amount of sparking and consequent cutting away of the

metal. The bobbin of the former machine occasionally worked loose on the wooden hub, so this should be looked to, also that it runs perfectly true.

The coils of wire on the bobbin of the Siemens machine have occasionally become loose at the end, but with proper care this defect should never occur. It is not prudent to purchase a second-hand machine without either seeing it at work or thoroughly testing it by means of a galvanometer and a battery. The connections of the magnet coils should be undone, and each tested separately. A circuit may also be made through the brushes and the bobbin, so that by turning the latter round any faulty coil would be ascertained.

Bürgin's machine (Franklin pattern) is better for getting at and for repairs than any of the other kinds. The rings can be removed and rewound, and with a slight alteration in construction it would be possible to take out any faulty segment of a ring and substitute another without interfering with the other bobbins. For general purposes this machine can be highly recommended, especially as it gives a current of sufficient electro-motive force to enable from

three to five lights to be maintained in series, and at the same time the current in circulation is sufficient to heat up the carbons so as to get the full effects of the luminous crater.

For general purposes this number of lights will be found most practicable. Where at times a less amount of light is required the reduction can be economically made by working alternate lamps from different machines, one of which may be stopped and the power saved.

For places free from dust and smoke the Crompton lamp gives excellent results when worked by this machine; but in iron works, mills, and the variety of sites where the atmosphere is charged with steam Hedges' gravity lamp will be found less liable to get out of order, and to be more within the knowledge of the man in charge.

For street lighting probably the Brush and Siemens alternating current system are the most suitable. The smaller lights as given by both these systems are the best, from the fact that streets are often too narrow or there are difficulties in the way of fixing the more powerful lights so as to get their full effect.

The lamps used with these systems have worked well for the street lighting in the City, where the former are fixed on the top of the ordinary lamp-posts while the latter are on special columns about 20 feet in height.

Where very powerful arc lights are required, and the circumstances of the case admit of such being used, the continuous current Gramme machine working the Brockie lamp is exceedingly economical, and the light well dispersed from the large area of the heated top carbon.

For dock purposes probably the single light system still remains the best. At the northern extension of the Liverpool docks the author has used self-supporting lattice work beacon poles about 2 ft. 6 in. square at the base and 10 in. at the top. Serrin lamps are slung in cylindrical lanterns 75 feet from the ground, each lamp being worked by an **A** Gramme machine of 6000 candle power. The light is sufficient for all dock purposes for a radius of over 100 yards from the post, which is firmly fixed on to a cast iron base let into the ground. This arrangement, in which all trussing and guy lines are done away with, has stood remarkably well, no damage being done in a

recent storm which blew down several of the ordinary guyed posts.

The great advantage of the single light system is its great simplicity and the durability of the machines. At Liverpool the same machines are at work nightly which have been used for a variety of contractors' work during the last five years.

By means of an apparatus called a *deviator* any one of a number of machines can be stopped and another substituted for it without extinguishing the light for more than a second; an alarm signal bell, worked by the current, calling the attendants to the faulty machine or lamp.

All the machines mentioned above will work incandescent lamps, a choice of which can hardly be decided on at present. The purchaser should, however, insist that the lamps are carefully balanced; that is, each contain a filament of similar resistance. If this is not so, after fixing he may find that his lights vary from five to thirty candles according to the varying resistance of the carbon filaments allowing more current to pass through one lamp than another.

Setting to Work.

After securing a good machine driven by an efficient, steady motor the first care will be to see that the conducting wires are continuous and that the lamp is joined up right. In alternating currents the poles will be the same, but with continuous currents the positive wire must of necessity lead to the positive carbon, which can always be immediately seen by its being brighter and hotter than the negative. A very good plan to test a machine, and at the same time to discover its poles, is to work it through an artificial resistance, which is best made by taking a piece of iron wire of the proper length (see table) to give the resistance and bending it up into a spiral. Without wasting carbon the machine can thus be run and tested, and an ordinary pocket compass will immediately tell the direction of the current by imagining a man to lie on the positive wire, the current flowing from his feet towards his head, and his face towards the magnetic needle. Then under the influence of the current the pole of the magnet which when free turns toward the south will turn to the

right hand of the man. When the positive wire is found it should be marked at intervals throughout its length. The brushes should now be adjusted in a position where they give out the least sparks, and after giving them a slight pressure on the commutator they should be fixed and not taken off.

It is a very bad plan to take the brushes off in order to interrupt the current. A separate contact breaker should always be provided for this purpose. The brushes should occasionally have their positions shifted laterally along the commutator to keep the wear even. It is a question whether it is a good thing to use oil or not. If proper care be taken at first the metal will get burnished so hard that the wear after a short time will be inappreciable.

With incandescent lights the leading of the wires is a more difficult task, and should always be done by some one acquainted with the subject. There are three plans of working in general use—1st, by placing the lamps in series; 2nd, in multiple series; 3rd, in parallel circuit.

No. I. Lamps placed in series are strung in a line so that the current passes from one to

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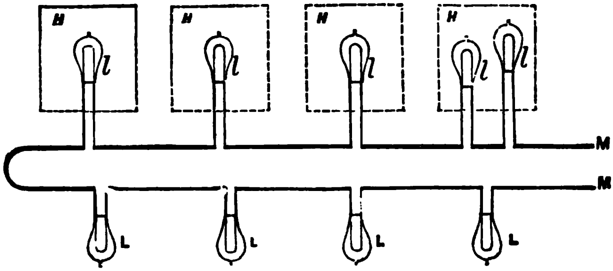
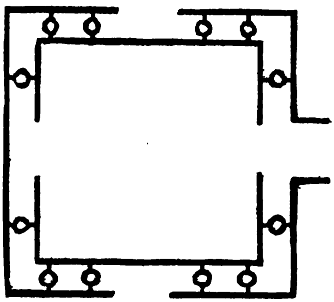
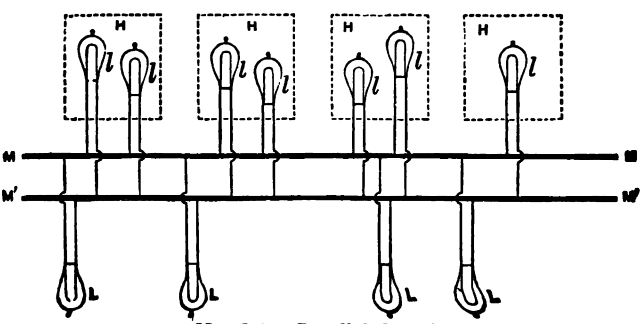


No I.—Lighting in Series.



No. II.—Multiple Series of 3 Lamps in paralle circuit.



No. III.—Parallel Circuit.

the other. This is the most economical plan, as every lamp adds to the resistance of the line, and the waste of energy in the conducting wire is diminished so that a small cable can be used; the objection to the plan is that a break in any part of the line extinguishes all the lights, so that it is necessary to employ an automatic circuit closer between each lamp.

No. II. Instead of each lamp forming a break in the line five or more are so fixed that each obtains a proportionate part of the whole current, and the electro-motive force required is considerably reduced.

No. III. Parallel circuit is the simplest of the three plans, and is the one generally adopted. Here one or more lamps form a bridge or shunt between the conductor leading from the machine to the other which returns to it, so that each lamp added reduces the resistance of the external circuit. Any lamp being extinguished does not materially affect the others, but slightly increases the resistance of the circuit. From two to three lamps are generally used to form the bridge, and as the breaking down of one of these would affect the other a very ingenious plan has been devised by Mr.

Edmunds of running a third independent wire to make connection along its length with each of the short junction wires of the lamps in the bridge. This arrangement was used for the large chandelier of 600 Swan lamps at the Paris Opera.

M. Gülcher showed at the Paris Electrical Exhibition a number of his arc lamps at work together, apparently on the same circuit, but in reality by the way he arranges his wires it is equivalent to a separate wire from each lamp. He calculates the section of wire for a required arrangement and then finds out the diameter of the wire of which, say for twelve lamps, twelve strands of wire arranged cable fashion will conduct the current.

As a precaution against fire, where a large number of incandescent lamps are employed, a fusible *cut-off* should be inserted in the circuit. In the event of too much current being sent through the wires, this would be melted before the latter became dangerously heated.

Several lamentable accidents having occurred through utter ignorance of the management of the powerful current given by electric lighting machines, all persons should be

cautioned as to touching any part of the apparatus whether in action or not.

The following directions are given as a guide, which could be altered to suit the special requirements of the case. They should be posted in a conspicuous place:—

DIRECTIONS FOR WORKING ELECTRIC LIGHT APPARATUS.

ARC LAMPS.—The long carbon should be placed at the top, and should have a blunt point. It burns twice as fast as the bottom one.

CAUTION.—Never touch the carbons or working parts of lamp without shutting off the current by means of the switch. Never put out the lights by taking off the brushes.

THE SWITCH—Should be kept always 'central' during the day, and the lights can be worked from either machine, and started or stopped by turning the handle in the direction marked.

GENERATOR.—The lamps, lubricators,

and the driving belt should be looked to every day; the brushes should be taken off and cleaned at least once a week. When put back they should be moved laterally to a new place, so as to equalise the wear.

Revolutions of Generator per minute ________

Revolutions of Engine per minute ________

NOTE.—The speed may be slackened if the carbons are found to flare.

On no account must the circuit of the current be shortened or the position of the wires altered.

IMPORTANT.—Never touch any part of the electric lighting gear with both hands without first ascertaining that the current is off, or you will make yourself the conductor of the current and receive a severe shock.

Always use an oil can with a copper spout when oiling the machine. Never cool a heated machine with water.

The whole of the electric lighting gear is under the charge of

Name ________________________________

If alternating currents be used, or a machine

of very high electro-motive force, as in the Brush system, it is dangerous to touch any part of the gear at all when in action, especially if standing on metal or on the damp ground.

When experimenting with these high tension currents india rubber gloves will be found to prevent shocks being felt.

Cost of Working.

In comparing the cost of electric lighting by means of the voltaic arc with that of gas or oil care must be taken to ascertain first whether the quantity of artificial light required warrants such a comparison being made.

With all powerful lights there must be a certain amount of extravagance compared with illuminants of less power.

Two candles on the table in a room will illuminate it sufficiently for ordinary purposes. If two gas burners are used instead they do not appear to give the light due to thirty-two such candles, which they should do if up to the parliamentary standard of sixteen candles each.

The room is nevertheless very differently lighted. With the gas the whole of it is illuminated, consequently there is more loss by absorption of the rays than there was with the two candles, which only lighted the area in their immediate neighbourhood.

In order to make a fair comparison the area to be illuminated should be large enough to utilise the light in such a manner that the actual amount of light should not be more intense than with the illuminant previously employed.

If applied properly this will be the case, unless there are numerous projections and recesses likely to cast shadows, when it would be decidedly preferable to light by means of incandescence, or fall back on gas.

If lighting by incandescence becomes the practical success its advocates believe it will, it is still doubtful whether it will ever be sufficiently economical to warrant its superseding gas in all cases.

Although Mr. Edison says to the contrary, it is a question whether heat for cooking purposes could be practically produced at all, and even if it was the cost would be enormous.

Theoretically the production of electricity in quantities appears to be far the cheaper plan of utilising the energy stored up in the coal or other fuel employed. This especially appears to be so if the quantity of coals used to produce a given effect of electric light are contrasted with the amount of coal consumed in making sufficient gas for a similar effect for instance.

The electrical machine used at the South Foreland lighthouse produced with one horse power 1·250 candle power.

An average steam engine may be taken as using 3 lbs. of coal per horse power. Therefore 1 lb. of coal elicited by the electrical machine 417 candle power.

In lighting by gas 6 cubic feet give 18 candle power if the gas is fairly good, so that 417 candles would be equal to 139 cubic feet of gas.

A ton of coal yielded 10,000 cubic feet of gas, so that 30 lbs. of coal would represent the 139 cubic feet of gas necessary to furnish the same amount of light afforded by the electric candle with 1 lb. of coal. Allowing for half the weight of coal returned in the form of coke when converted into gas, the result is, that

15 lbs. of fuel were consumed to produce the luminous effect of what would be obtained with the electric light with 1 lb. of fuel.

This statement, though correct in itself, is calculated to mislead if taken as a basis of comparison with every day practical results, as it is quite impossible to utilise in practice anything like fifteen times as much light as would have been obtained if gas was employed.

The measurement of the electric light was taken by the photometer, which measured the total intensity of the naked beam under the best conditions. These can hardly ever be realised in practice, though for lighthouses the efficiency is very high. The carbons were set with the front edge of top carbon nearly on the centre of lower one. This in itself, according to the committee of the Franklin Institute, gives a gain of over 60 per cent. on the light, as the top carbon forms a natural reflector, and tends to throw the light forward. An allowance must also be made for the extra power which is required to start the electric machine.

With a gain of fifteen to one there is room for a considerable reduction, and sufficient saving shown to warrant the introduction of

electricity apart from the hygienic view of the question.

Where the electric lighting by means of the voltaic arc can be suitably employed it may safely be taken as costing *one-third less than gas* —gas at average price paid here; price of gas in France is about double.

Where no gas exists the first cost of instalment of the necessary plant to produce the electric light would be much less than that required to erect gasworks.

Sir William Thomson states that an arc lamp is ten times as economical as an incandescent one, mainly from the fact that in the former the temperature is enormous while in the latter it can be only as high as the carbon filament will stand. The analogy may be continued and the incandescent light proved to be more economical than gas for a similar reason; which certainly holds good with the consumption of the latter. All the improved burners are constructed to use a large volume of gas internally mixed with a proportionate amount of air so as to secure a high temperature of combustion.

Dr. Siemens, of Berlin, has taken advantage of this and has designed a special form of gas

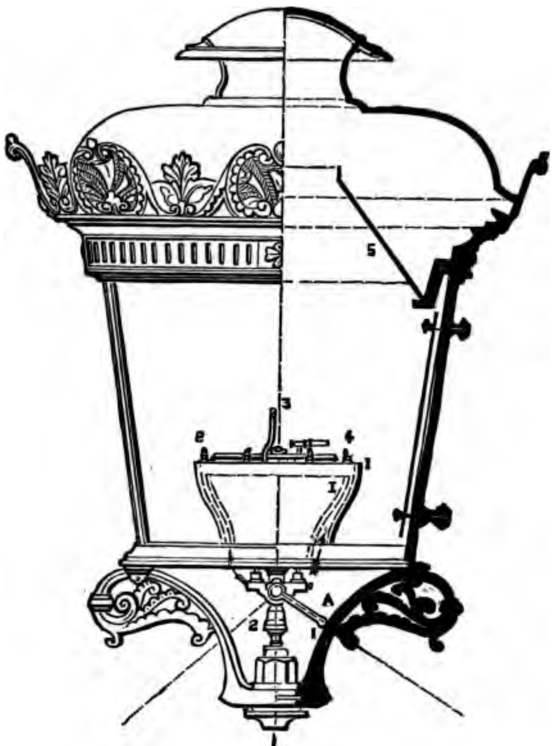
burner with a regenerator in which the air necessary for combustion is heated prior to being used.

The temperature of the air is thus raised to 500° centigrade, and the quality of the illumination of the gas very much increased.

Street lighting by electricity presents many difficulties, and where streets are narrow gas is still the best illuminant. A new form of gas burner designed to give similar illuminating power to the electric light used for the street lighting in Paris has been tried in competition with the latter. As this gas burner is arranged so that the light can be turned down to that of an ordinary street lamp at the same time as the electric lights are extinguished in the neighbouring street, a fair comparison can be made.

After a series of trials the Jablochkoff electric candles in the Avenue de l'Opéra were found to be equal to two burners, consuming 49·4 cubic feet per hour of the pattern of those in the Rue du Quatre Septembre. The gain is apparently on the side of electricity, but as the gas illumination is reduced after midnight to 4·9 cubic feet per hour, the total cost is less by gas than by electricity.

pp. 102-103.



Phare Gas Lantern and Burner, of the pattern used in the streets of Paris.

By turning the handle A in the opposite direction the ring burner is extinguished, leaving the one in the centre alight.

It is the difficulty in the way of reducing the light that renders arc lighting too expensive if the lamps are fixed on the ordinary lamp-post. For instance, if a good effect is produced by placing a lamp on every third post to turn one of these lamps out would necessitate a very dark space between the lights left burning. With incandescent lamps fixed on each lamp-post the matter is simpler but expensive in maintenance, as the advantage of having a burner which consumes no air is valueless in street lighting. Where the width of the streets permits, the best plan would be to sling the lamps midway across, after the fashion of the old oil lamps. An arrangement might easily be made to draw the lamps to the side and trim them either from a window of a house or lower them on to the pavement. A lamp containing two sets of carbons is generally employed for street lighting, which enables the light to be maintained a long time without the disadvantage of using long carbons.

The Brush system is well adapted for street lighting where the ordinary posts are used, if the cost of using the light all night is set aside.

It is thus employed in the City, the power being supplied by an engine fixed at the company's works two miles away.

An interesting official report as to the cost of this system has been published by Colonel Festing, the assistant director of the South Kensington Museum, where electric lighting has been employed for some time.

The following are the working cost for a period of 359 hours and an abstract of the report on same:—

	£	s.	d.		s.	d.		
Carbons .	18	9	0	or	1	0	per hour of lighting.	
Oil, cotton waste, &c.	4	11	6	„	0	3	„	„
Coal . .	11	14	0	„	0	8	„	„
	34	14	6	„	1	11	„	„
Wages .	34	7	6	„	1	11	„	„
Total .	£69	2	0	„	3	10	„	„

'The consumption of gas which used to be at the rate of 16s. an hour would for the same period have been £287 4s. The saving on working expenses has therefore been £218 2s., or at the rate of about £420 per annum.

'The outlay was as follows:

Cost of dynamo-electric machine . . .	£400
„ lamps and fixing; conducting wires, &c.	384
Cost of steam engine and fixing; shafting, belting, &c.	420
	£1204

'As, however, the steam engine is capable of driving two such machines, the cost of the machinery and apparatus for lighting the court may be said in round figures to have been £1000, on which outlay the saving on working expenses, as compared with gas, represents 42 per cent. per annum. The machinery at present shows no sign of deterioration from wear or tear, nor do I see any reason to expect any great expense on this score. I hope that with increased experience we may obtain greater steadiness in the light, and perhaps even some slight diminution of working expenses.

'I propose next to try similar lamps in some of the picture galleries and in the art schools, in which latter there are great complaints of the bad state of the atmosphere in the evenings caused by the gas.'

[Since this was written the Lane Fox lamps have been in regular work in the library some time.]

The Brush system is very largely employed in the United States. In Albany 300 arc lights replace 2000 gas and oil lamps, 200 lights are installed at Denver, Colorado. The average price paid per annum for the supply of a 2000 candle light is £30.

The carbons used in this system are priced

very much lower than those used in the other systems; this item alone makes a considerable difference in the cost of working. The average cost per hour for carbons 13 $^{m}/_{m}$ diameter, the size generally employed for Brockie, Siemens, Crompton, and Hedges, should not be more than $1\frac{3}{4}$d. if the best carbons are used, which burn at the rate of $2\frac{5}{8}$ inches per hour.

If they burn faster than this it is because the current is too powerful, and a larger diameter should then be tried.

The total working cost of a powerful light from a Gramme, Siemens, or Bürgin machine, where several are worked by the same engine, should not be more than 4d. per hour. The items would be made up thus: fuel, 0·72d.; carbons, 1·75d.; oil, 0·1d.; attendance, 1·0d.; interest and repairs, 0·43d. This low price would not hold good without at least 12 lights were operated, or the charge for attendance would be more.

The author has endeavoured to obtain some statistics of the working expenses of some of the most important recent installations. The table on the opposite page contains some particulars of cost. By the word 'contract' is

Description of Place lighted.	Name of System.	No. of Lights.	Nom. Candle Power per light.	Height of Lamp above ground.	Floor Area in square yards.	No. of Gas Burners superseded	No. of Machines.	Name of Lamps.	Approximate Cost per light per hour.	Time of Experiment.	Notes.
Cannon Street Railway Station	Gramme continuous current, Engl. type	inside 8	5000	35′ 0″	11,000	95*	2 2 exciters	Brockie	6·39d.	6 hours per day for 6 months	These Stations are lighted at a contract price, which is enhanced by special conditions.
Charing Cross Station . .	Brush	inside 16	2000	14	10,092	85*	1	Brush	2·75d.	8 hours per day for 6 months	
King's Cross Station, G.N.R. .	Bürgin	inside 12	5000	30′ 0″	22,000	12 burners, 100-candle power, and 60 15-cndl. power.	4	Crompton .	2·9d.	7 hours pr. day	
Blackpool Esplanade . . .	Siemens continuous current	4	8000	60′ 0″	Distance lighted 750 yds.	54 per ct. less than gas	4	Siemens	2s. 2d.	5 hours pr. day	
Eastern Railway Station, Berlin	Siemens alternating current	14	400	23′ 0″	7802	. .	. .	Siemens	6·3d.	. .	Contrct. price. Net cost about 4s. 8d.
Liverpool Docks, Shed Interiors	Gramme, A. type	2	3500	22′ 0″	12,133	3 sun lights = 90 burnrs	1	Hedges' Gravity form	3·75d.	. .	Experimental
Wharf, Ipswich .	Bürgin, Franklin type	3	3000	Varies from 20′ 0″ to 30′	. .	30 gas jets, 15 oil lamps	1	Andrews	4·5d.	. .	2 wharves lighted, one 450 yds. away; cable laid in water. Total circuit 1000 yds.
Liverpool Docks, Beacon Lights	Gramme, A. type	1	6000	75′ 0″	22,000	. .	1	Serrin	4·2d.	. .	Several of these lights are used for the general illumination of the locks & entrances.
British Museum	Siemens continuous, also alter. currents	4 large 7 small	. .	. .	. .	No gas used	5	Siemens	Total 6s.0d.	. .	Light estimated to be equal to 250 Argand burners, at 5 cubic ft. per hour.
Picton Gallery .	Gramme	3	6000	Light reflected upwards	. .	. .	3	Serrin	7d.	. .	Gas cost 7s. per hour.

* The light is much greater than that from the Gas superseded

meant that the price given is that received by the company supplying the light.

From this table it will be seen that where considerable amount of light is required electricity is cheaper than gas, especially out of doors, as in the Liverpool docks. The comparative cost of incandescent lighting can hardly be estimated at the present time; it is probably more than gas, and will be so until the current is generated at a central works and supplied like its older rival.

In country houses, however, or places where there is no gas, the first expense is below that of starting a private gasworks or using candles; and where water power can be obtained the maintenance of the light resolves itself into the wear and tear of machine, renewal of lamps, and attendance, which would be less than with oil or candles.

The following table appeared in the first edition of this work. It may be interesting to compare the working cost at present with that formerly charged. The systems here noted are nearly all single light, so the first cost was much higher than were those noted in the previous table.

TABLE OF LIGHTING BY VOLTAIC ARC.

Name of System.	Where employed.	Description of Place lighted.	Time during which cost was noted.	Cost per light per hour independent of interest and depreciation.	No. of Lights.	No. of Machines.	No. of Gas Burners superseded per light.	Equivalent No. of Gas Burners considered equal to in efficiency for each light.	Remarks.
Gramme	Northern Railway of France	Goods Station	Two years .	5d.	6	6	22	52	Partly open. Partly covered.
Ditto .	Rouen . . .	Inclosed workshops	Two years .	4d.	2	2	—	—	Worked off Factory Engine.
Ditto .	Tay Bridge Works .	Open air Contractors' works .	Six months .	1s. 5d.	2	2	—	—	Old pattern machine, working through 300 yds. of conductor.
Siemens	Iron Works .	Open yard .	Three months	11d.	1	1	—	—	Normal power of lamp 1000 candles.
Gramme	Woolwich, Royal Arsenal	Carpenters' shed . .	—	8d.	2	2	—	75	Nothing allowed for power.
Lontin .	Western Railway of France	Goods Station	Six months .	5½d.	6	1	—	70	—
Duplex Gramme	Paris . .	Avenue de l'Opéra	Six months .	11d.*	16	1	Average 5	10	Street Lighting by Jablochkoff candle.

* Price includes wear and tear and repairs.

Result of Lighting by Electricity.

Casting a retrospective glance on the various installations of the light during the past four years, the period of its existence in this country as a practical illuminant, we find its use developing with the greatest rapidity. As originally introduced the electric light consisted of a single powerful light which, except in certain cases, was a sort of white elephant to the general public, who could not put it to practical use.

This in some cases was adopted; for instance, the electric light has been used as early as 1877 at the Liverpool docks, and these same Gramme machines and Serrin lamps have been working almost nightly since, the only repair necessitated being the renewal of the brushes, and, with a slight exception, the whole of the plant may be considered as good as new.

The lighting of the St. Enoch Station at Glasgow gave considerable impetus to the popularity of the new light. The Queen-street Station soon followed, and was only rivalled by the Brush light at the Liverpool-street Station of the Great Eastern Railway.

The South-Eastern Railway directors very properly gave their two principal termini to the exponents of the Brush and Gramme systems, who have each carried out their work so well that it is almost invidious to make a choice. This is not altogether so as regards the two older stations, King's Cross and Paddington, where the Crompton light in the former entirely eclipses the Brush.

In private hands the latter system seems to give most excellent results. Messrs. Peek, Frean & Co., who have substituted it for gas in their factory, say that, besides being able to see clearly the slightest variation in the colour of their goods, they effect a saving of 20 per cent. over gas at 3s. per 1000 cubic feet.

Taking the principal systems and glancing at the places where, by means of the voltaic arc, electric lighting is successfully employed, the list embraces every variety of trade, and of more importance is the fact that out of the hundreds of installations there is not one where the light has been discarded.

This remark also applies to street lighting, where, although in point of colour and economy gas has often an advantage if a reduced illumina-

tion is required after midnight, the public having once seen the streets properly lighted are not likely to go back to the old standard.

The electric lighting of the City is certainly a success except in the material one of cost. From the southern side of Blackfriars to the eastern end of Cheapside the thoroughfare is brilliantly illuminated by means of thirty-two electric lamps on the Brush system maintained by a single generator fixed at the company's works in Lambeth. Each of these lights replaces five gas lamps with a greatly increased lighting effect. From the Surrey side of London Bridge to the Mansion House thirty-two electric lamps on the Siemens system replace 138 gas lights. Twenty-eight of these are worked from two alternating current machines, and the four large lights are each fed by a separate generator, the whole of the machinery being fixed in a cellar in Swan Lane. The four large lights were originally suspended near the top of lattice work posts at a height of about 89 feet from the ground. This was found not to illuminate the roadway sufficiently, so the lamps have been lowered to about 40 feet. Setting aside this drawback, the general effect

from these large lights is very good, the globes being so arranged that the rays are well dispersed and the shadow of the post avoided.

The remaining portion of the City district is lighted with lamps worked by the Weston machine, but owing probably to some defect in the carrying out of the work the lamps work irregularly, although the same system is very satisfactory in the metropolitan stations. The great advance made within the last twelve months in the direction of street lighting will probably have the effect of extending the area lighted by electricity.

Farringdon-street, Aldersgate, and Moorgate Stations are lighted from a central generating station at Aldersgate.

The Jablochkoff system, which has been working uninterruptedly on the Thames Embankment since the early part of 1879, was, when first introduced, four times as dear as gas, but now is contracted for at almost the same price.

Incandescent lighting was practically demonstrated a success by its use in Sir W. Armstrong's house in 1879, the power to work the generator being furnished by a waterfall actua-

ting a turbine. A room 33 feet by 20 feet is well lighted by eight Swan lamps, each of which is equal to 25 candles.

Since then the manufacture of these lamps has much improved, and this form of electric light has been applied for purposes varying from the illumination of a theatre to a railway train.

Incandescent lamps have also been tried in coal mines as a substitute for the safety lamp, which is not always reliable. It is doubtful whether electric lighting is adapted to this use, as it offers considerable difficulties of maintenance by reason of the wires and insulation being destroyed by the pressure of the roof of the pit and the wet.

A very large measure of success has attended the application of the electric light to ships.

For search lights it has for a long time been introduced both in the English and foreign navies. A large Gramme or Wild machine was used, and the light concentrated by means of a powerful lens and reflector. Experience shows that it might be practicable for an attacking party to disable the lamp and extinguish the light by firing at it. To obviate this the lamp and other vulnerable parts are now kept below,

and the light conveyed by a tube to a reflector, whence it is turned in the direction required.

With a few exceptions electricity was not used for the interior illumination of steamers until incandescent lighting became known. The first ship thus lighted was the Orient Steamship Company's *Chimborazo*, five lights being placed in the saloon and three in the steerage. The arrangements were carried out by the author, who used André's incandescent lamps, working in series from an **A** size Gramme machine in such a manner that the whole current could be turned into an arc lamp for deck purposes when required.

For engine-room lighting, steerage, and passages it is however more economical to use arc lamps of about 400 candle power. This plan has been adopted for the Inman Steamship Company's fleet, their latest vessel, the *City of Rome*, also having the saloon, passages, and staterooms lit with Swan's lamps. By placing one lamp at the intersection of two staterooms and the passage the light is economised, and either room can be darkened by drawing a curtain.

In ship lighting particular attention should

be paid to the insulation of the conducting wire, which should be laid separately, so that in the event of their becoming wet they will not be short circuited.

It is found most convenient to place the dynamo and engine on the upper part of the engine-room and use the belt frictional gear as described on page 69.

A direct acting high speed engine is not to be recommended on account of the vibration and noise.

The governor must be of a special spring kind. Ball governors will not act in a sea. The exhaust should be coupled to the condenser, and also allowed to go away free. By means of a cock the latter need only be used when the ship is in port, and the advantage of a vacuum secured when the vessel is in motion.

Measurement of Light and Current.

The measurement of powerful lights, whether from electricity or gas, presents certain difficulties which are not yet altogether over-

come. With electricity the principal objection is the colour, which varies from that of the standard candle or carcel burner. The latter has been used in France: it burns 42 grammes (648 grains) of olive oil per hour, with a given height of flame, and a fixed diameter of wick. It is considered equal to 9·4 standard candles.

The light given by both these standards is yellow while that of the arc is white, and this difference renders exact comparison impos sible even with the interposition of a red or glass screen. The magnesium light and the incandescence of a platinum wire have each been recommended as a better form of standard. The relative amount of red and blue rays in the spectrum of the voltaic arc has been proposed as a good basis of comparison; the admirable photographs of the spectrum taken under varying conditions by Captain Abney show that this plan could be adopted. The difference in the sight of two or more observers would still tell even against this method, which appears to be the one least susceptible of error. The term standard candles is wholly inapplicable to powerful electric lights, and it has been suggested by Mr. Preece and others to

rate the light of being capable of illuminating a given floor area to a certain standard. As a rough measurement the shadow test is the simplest, which is easily arrived at by holding two sticks at such a distance from each of the two lights to be examined that the shadows thrown by the sticks are equal, and then measuring the distance from each light required to produce the same effect. It is necessary that the lights should be fixed at a similar height, also two sticks should be used, and the shadows compared by more than one observer.

The want of colour of the electric light, which has already been alluded to as a questionable advantage, for some purposes is a positive objection. For instance where great penetrative power is required as in lighthouses, electricity stands first as the most powerful illuminant for fine weather, but in a foggy atmosphere when a light is most needed it has not even so much penetrative power as a gas or oil lamp. The reason for this will be more readily understood by comparing the spectrum from the light of the voltaic arc with that from a gas or oil flame. The violet and blue rays,

which are the most refrangible, are present in a much larger degree than in a gas or oil flame, and these refrangible rays are more easily absorbed by fog and smoke than those in the other part of the spectrum. According to Dr. Barnard, of Columbia College, New York, so great is this effect that in time of fog an electric light may show but a moderate superiority over an oil lamp, which it exceeds in the proportion of 10 to 1. This objection has doubtless kept back the extension of its use for lighthouse purposes in this country; on the other hand, in France it is to be employed at all the principal stations. That at Cape la Hève has been constantly working since 1863, the generators being two Alliance magneto-electric machines with permanent magnets. Magneto-electric machines have given such satisfactory results that they are to be used for the lighting now in progress, the De Meriten type having been adopted.

Some very interesting experiments were made by Dr. Hopkinson to measure the quantity of different colours of light in the electric arc. At 240 revolutions a minute the arc gave one hundred and eighty times as much red light

as a candle, and three hundred and sixty times as much blue light. When the speed was 520 revolutions the red was 1300 candles, and the blue 4860. At 600 revolutions the red light was 2400 red candles, and the blue light 10,100 blue candles.

Measurement of Current.

It is convenient to be able to ascertain easily what amount of current is given by a generator, more particularly when incandescent lamps are employed, which are said to give a certain amount of light using a given quantity of current. The instruments used are known by different names, but all indicate the unit of current now called an *ampère*, formerly a *weber*. That made by Messrs. Siemens is called an electro-dynamometer, and is wound with two thicknesses of wire so that either alternating or continuous current can be measured. M. Deprèz has constructed one of galvanometer form which indicates on a dial the current flowing round it. Professors Ayrton and Perry have an improved form of galvanometer which is furnished with a simple means of testing the readings. The cable encircling the needle is

composed of a number of strands, each of which are insulated and can be joined for use in multiple arc by means of a commutator. When not joined a weak current from a battery may be used to check the readings. Mr. Andrews also has a still simpler form which indicates the current strength on a dial, and after being once calibrated requires no further adjustment.

Storage of Electricity and Transmission of Power.

This subject has received considerable attention lately with the introduction of what is known as Faure's accumulator. Up to the present time, however, nothing has been done practically on a large scale, chiefly from the difficulty attending the use of such batteries, which has been already explained. An experiment has been made by lighting the smoking-room of the Junior Carlton Club by incandescent lights supplied by the current stored in 40 Faure's cells, which are charged and brought to the club daily. Although the light is bril-

liant and extremely steady the cost must be very considerable, and a wire direct from the generator would operate a much larger number of lights. The same plan is now adopted for the lighting of the Pullman car train to Brighton, and found to work well, though not so economically as if a small dynamo and motor were carried on the locomotive.

Transmission of Power.

Probably this question is less understood than any other in which powerful electrical currents are employed.

It is often stated that the great natural forces contained in the rise and flow of the tide and in the currents of our river is at last to be made subservient to man's will at any distance. It is, however, only in certain situations where a benefit would accrue from the use of electricity for this purpose over other well known means of transmission, such as wire ropes, compressed air, or water pressure. In some instances these agencies cannot be adopted without great outlay both in first cost and maintenance, then the use of electricity may be quite practicable. The method of obtain-

ing an electric current for the performance of work is analogous to the generation of steam in a boiler, fuel being used in both cases. If zinc were consumed in a battery the cost would be nearly thirteen times as much as the use of coal in a furnace, and a battery is impracticable. With a steam engine, after deducting the loss in transmission and the contrary currents set up in the second machine, the loss is so great that only under certain circumstances could this source of power be entertained. Where spare water power can be utilised the efficiency of the prime mover can be set on one side, and the question resolves itself into the efficiency of the dynamo machine producing the electric current and that of the machine which retransforms electricity into work.

The first has been thoroughly investigated by Dr. Hopkinson and found to be from 86 to 89 per cent., but the further loss is occasioned by the return current in the driven machine, which is produced directly it begins to rotate; that is, by generating an independent current opposed to the original one.

When the return current is equal tc the

primary one, the amount reclaimed is just one-half. From this must be deducted the amount of work lost in obtaining the current, which brings the net amount transmitted to about 44 per cent.

To effect the transmission it is only necessary to couple two machines together by leads in the same manner as if the second machine was in the place of a lamp. The most effective speed for the second machine is from one-half to two-thirds that of the first: almost any of the well known systems of generators will act if coupled up thus. In certain cases special machines have been designed. In France, where electrical transmission is in practical work, the ordinary A-sized Gramme machine is commonly used.

M. Menier has applied electricity for ploughing in the neighbourhood of his works at Noisel, at a distance, in some instances, of nearly three miles from the turbine which was used to produce the power. It is, however, very questionable whether this plan would work well with the ordinary labour to be found on a farm. For ventilating puropses it is far more suitable, as a rotary fan can be worked in out of the

way places, such as in the roof of a public building, and be used either to exhaust the foul air or supply a current of fresh air. This plan is to be adopted for the ventilation of the new Hôtel de Ville in Paris, and has also given very satisfactory practical results for the ventilation of a coal mine. The most interesting application of electro-dynamic force has been as a motor for use on railways and tramways.

Its introduction is due to Messrs. Siemens and Halske, of Berlin, who first adapted a light railway constructed for the transport of building materials between the Anhalt station and Great Lichterfeld, a distance of 2·45 kilometres. The arrangements consist of a carriage containing a dynamo machine electrically connected through the insulated wheels of the carriage to the two rails. These being laid on wood sleepers are insulated one from the other, the joints being made by elastic strips of metal soldered at the foot of each rail. Another dynamo machine driven by a stationary engine produces the necessary current which is conveyed by the rails. The speed is fixed by the government at 12½ miles an hour, but the carriage is capable of travelling at double this

speed with the full load. The secondary current, which was shown to depreciate the value of the force transmitted under ordinary circumstances, is not detrimental with a carriage in motion. The reason is, that the extent of the secondary current and its strength depends entirely on the speed at which the carriage travels, so that if the force of the primary current from the generator is such as to greatly accelerate the motion of the carriage the counter-current is also greater, and *vice versâ*; the speed is thus always regulated automatically. An electrical tramway constructed by the same firm attracted considerable attention at the recent Electrical Exhibition in Paris. The current was in this instance led to the machine by means of a flexible connection attached on one end to the car and on the other to a small carrier which ran in a tube connected to the conductor from the dynamo machine. This arrangement would be advisable only under special circumstances; where there is an objection to having electrically insulated rails the best plan would be to construct a light overhead tramway, similar to the overhead railway in New York. On account of

the small weight of the tramway carriage and electro-motor the proportions of the superstructure need not be unsightly. On a horse tramway at Charlottenburg the motor travels on an overhead cable line and draws the cars which are underneath.

Electric Light as compared with Sun Light.

The light given out from the voltaic arc is generally considered to more resemble the pale moonlight than the warm effect of the sun's rays. On investigation this is found not to be so, and if we set aside our natural inclination to lights of artificial colour, like that from gas and oil, we find that after all the voltaic arc resembles the sun in many ways. We have long regarded the sun as white, but in reality he is blue or bluish, and it is the effect of the atmosphere which causes him to look white, in the same way as it makes him appear red, orange, or yellow when setting.

As we cannot produce an artificial atmosphere to tone down the blue effect from the

arc, we must effect this by dispersing the rays through glass globes, which give the best effect if slightly coloured in the manner described on page 78, so as to coincide with our established ideas fostered by the use of gas and oil.

The chemical rays at the violet end of the spectrum are very largely represented in the voltaic arc, and enable us to make use of it for photographic purposes, and also for bleaching. The larger portion of these are invisible rays which, although not considered to be injurious to the human system, have a bad effect on the growth of plants. Dr. Siemens has proved this by some most interesting experiments with fruit trees and flowers, which he subjected to the continuous light from an electric source. He found these to develop much quicker than when they are allowed to have a periodical time for repose; but to produce this effect it was necessary to inclose the light in a glass lantern, or a reverse effect was produced, and the leaves became withered. The glass stopped out a large amount of the invisible rays from the violet end of the spectrum which apparently had a bad influence, although in the sun these

rays are also present and appear to do no harm. In the north of Europe, where for a large part of the year there is continuous daylight, not only are the size and colour of the flowers developed by the light, but their aroma is intensified; and this applies to all parts of the plant. The intensification of the flavour of some garden plants, such as celery and onions, renders them almost uneatable in Scandinavia. All the wild and cultivated fruits that can be ripened in Norway have more characteristic flavour than those grown in the south, but in the region of continuous sunlight they become deficient in sweetness, probably because there is not sufficient time for the conversion of the starch and woody fibre into sugar. From this it would appear that to secure the best results the length of exposure to artificial light should not be altogether continuous, but as near as possible imitating the average long summer day.

Electro-horticulture can hardly be said at present to have sufficiently advanced to be used practically; where, however, a source of water power is available the light may be produced at a very moderate cost. In such case Dr. Siemens finds that the cost per hour including

personal attendance is not more than 3d. per light of 5000 candles, and the plant would be available during the day for working the light machinery of the estate by the power transmitted through the conducting cable.

Fate of Gas.

Much nonsense has been written and said respecting the disuse of gas which will follow the introduction of electricity. The same was said of oil and candles when gas was introduced, yet more of both the former illuminants are used than ever.

The consumption of gas, instead of lessening with the introduction of electricity, has in most cases received an additional stimulus by the use of gas-heated boilers as well as gas engines. The public are being educated to a higher standard of artificial lighting. The brilliant effect of large spaces lighted by the electric light causes the present dimly lighted streets by comparison to look quite dark. A higher standard of gas lighting is called for, and shopkeepers and others who are unable

to adopt electricity do their best to keep up an appearance beside their more fortunate neighbours by an extra consumption of the older illuminant.

The products returned to the gas makers in the process of gas-making are a great source of profit. They would be more so if the gas companies were to extract the different useful substances contained in the products themselves instead of letting others take the manufacturer's profit. The Paris companies already do this, and find it a source of considerable revenue, one article alone, namely, sal-ammoniac (made from the water the gas passes through), increasing in demand every year, owing to the larger introduction of galvanic batteries for every variety of purpose.

The deposits of coke and graphite in the retorts are both necessary to the present means of electric lighting.

Gas will for a long time be used in private houses, the supply of which is far the most profitable source of revenue, the receipts from street lighting in London being only 5 per cent. of the total receipts of the Gaslight and Coke Company.

The sliding scale, confirmed in last session of Parliament, of allowing an increased dividend as the price of gas is reduced has now been some time in operation; for instance, with the South Metropolitan Gas Company the price charged is now 2s. 10d. per 1000 cubic feet and the dividend 12 per cent. At this price gas is as economical as coal for cooking purposes, and its more extended use would do much towards the prevention of fog, so complained of in all large cities.

The history of the gas companies here for the last seventy years is one that shows what private enterprise may do, and these owe their present prosperity to those men, like the elder Mr. Pendennis of Thackeray's well known story, who on retiring from business subscribed a few thousand pounds under a partnership deed, sold gas as a commercial article unrestricted as regards price, and went through a few first years without paying any dividend, wisely putting their earnings into new works. Their enterprise remains as a lasting monument, and as far as can be seen is likely to do so, for the various applications to which the electric light has not yet been found suitable.

CONCLUSION.

That electricity will be adopted wherever possible there is little doubt.

It surpasses by far in economy and beauty all other known illuminants. It is especially adapted for workshops of all kinds; dye houses, weaving sheds, spinning-mills, contractors' works, stores, halls and theatres, picture galleries, swimming-baths, and numerous other purposes, in all of which its application has resulted in success.

For matching colour in dye works the rays of the voltaic arc have a value beyond comparison with any other illuminant. All colours can be matched, the most difficult being the few shades the dyers call drabs.

It enables building operations to be carried on as well by night as by day, also the farmer may continue harvesting without stopping at sundown if the crop is wanted quickly. In short, when suitably applied there are few industries which need be suspended at all by reason of darkness.

From a hygienic point of view the use of

electricity should become extended from the fact that it does not pollute the air. Each gas burner may be said to require as much air for combustion as four human beings, while the electric light requires absolutely none, and consequently gives off no poisonous products.

That a certain amount of heat is radiated from the electric light is an established fact.

A careful investigation of the amount of heat radiated from the globe inclosing one of Lane Fox's incandescent lamps shows it to be one-sixth that radiated from a gas burner of equal illuminating power. This in itself is sufficient to recommend the speedy adoption of the incandescent light in theatres and public halls, where ventilation is of great importance, as well as the preservation of decorations. Although this form of light if applied on a small scale must be dearer than gas, the poisonous fumes from the latter have a most destructive influence on painting and gilding, which considerably augments the cost of repairs.

The protection against fire afforded by use of electricity has already been recognised by the French insurance societies. The recent destructive fires in theatres, which have caused

such a lamentable loss of life, will probably have the effect of hastening its introduction.

It is difficult to light any ordinary material by the electric spark. The wires are far less liable to be damaged than an ordinary gas pipe; if the connection is broken the worst that can occur is the extinction of the light. With the light hermetically sealed in a glass vessel absolute safety is attained, and with the addition of an exterior glass globe incandescent lamps could be employed in powder mills and in the larger galleries of coal mines.

With properly adapted apparatus no trouble ought to be experienced with the electric light. In nearly every instance where electricity has been reported not to succeed the objection has arisen either from the efforts of interested parties to prevent it doing so or by not having a sufficient number of electric lights to compete with the previous illuminants. This was the case in Billingsgate Market, where the so-called failure was due to the small number of Jablochkoff electric candles compared with the liberal supply of gas burners.

Summarising the applications of the electric light, it may be said to have given us a standard

of light hitherto unknown, and it can be employed under circumstances where any other illuminant would be useless. Where properly installed it is much healthier and more agreeable to the sight than any other light; badly arranged it is injurious to the eyes, and the effect is disagreeable.

In conclusion the author would advise intending users of the electric light to weigh for themselves the evidence both for and against its general adoption. If deciding in its favour you wish to adopt it, do not be led hastily away to take up any particular system, however successful, without being sure of its adaptability to your own particular case. Having obtained suitably adjusted apparatus, properly insulated wire, and especially carefully arranged the position of the lamps so that their maximum effect shall be attained, no further trouble should be experienced. The attendant in charge of the lamps, who should be selected as having some intelligence, will turn on the current after the machine has been running with an open circuit for a short time, the light will then continue until the carbons become exhausted, or in the case of

incandescent lights, until the filament gives out. No special attention should be required beyond seeing that the generating machine is kept properly lubricated, and that the carbon holders in the lamp are kept clean. With incandescent lights the substitution of one for another is the work of a moment.

It is advisable that the person in charge should be first examined by some practical electrician as to his knowledge of the properties of electrical currents and cautioned as to their dangerous character when improperly treated.

The wear and tear, setting aside that of the engine and boiler, will resolve itself into the wear of the commutator (which should be almost *nil*), the brushes, simple pieces of strip copper or bundles of copper wire, and the wear of the bearings of the journals on shaft which rotates the bobbin or coils. This ought to be amply covered by a depreciation of 6 per cent.

Very little wear is found to take place in the regulator, with the simplified forms of which clock work is dispensed with; the only parts requiring attention are the contacts with the carbons.

There is still reason to expect that great improvements will be made on the present practice of electric lighting. If machines worked by engines could be dispensed with altogether, and a simple secondary battery be found which would be free from the drawbacks hitherto inseparable from those in use, it would be universally adopted. An economical and efficient battery for household purposes has yet to be discovered. A step in the right direction is shown by the recent improvement of M. Faure, the further development of which may be expected on account of the numerous experimenters in this field of research.

It may be interesting to know that some years ago it was found possible to convert hematite iron ore into pure iron by a process in which the electricity produced, though small, could be utilised. The signal bells of a colliery were for some time worked by electricity generated in this manner.

In conclusion, taking a general view of the case, the introduction of electricity for lighting purposes has lead to beneficial results to the public. The wholesome stir it has made in some quarters has been conducive to great

improvements in the quality and price of gas supplied.

If it ultimately presses its older rival out of the field we can part with gas without regret, and illuminate our public buildings and private residences with a beautiful radiance which does not consume or poison the air we breathe nor cause explosions or conflagrations; and although this 'tricksy Ariel' has already had its victims nothing can be simpler than the means by which even the most ignorant persons can be protected.

ELECTRICAL MEASUREMENTS.

For the practical application of powerful currents for the purposes already described, it is unnecessary to go deeply into calculations which have frequently been considered by various authorities. Until the recent International Electrical Congress in Paris the terms of expressing the various electrical quantities were not fixed; they are, however, now represented by the following table:—

Symbol.	Electrical Quantities.	Nomenclature at Congress.
R.	Resistance.	Ohm.
E.	Electro-motive Force.	Volt.
I.	Intensity of Current.	Ampère (late Weber).
Q.	Quantity.	Coulomb.

The following propositions were also agreed to:—

'1. For electrical measurements, the fundamental units the centimetre (for length), the gramme (for mass), and the second (for time) are adopted.

'2. The ohm to be represented by the resistance of a column of mercury of a square millimetre section at the temperature of zero centigrade, 1·0486 metres long.'

The resistance of the voltaic arc is from $1\frac{1}{2}$ to 6 ohms. The Lane Fox incandescent lamps have a resistance of

about 60 ohms cold. It appears that with ordinary carbons and at ordinary atmospheric pressure no arc can exist with a less difference of potential than about 20 volts; and that in ordinary work with an arc about ¼ in. long the difference of potential is from 30 to 50 volts.

'3. The current produced by a volt through an ohm to be called an ampère.' The volt is rather less than the electro-motive force produced by a Daniell's cell.

That is, 1 volt equals ½ an amp. through 2 ohms. The Brush lamps are said to take 60 volts, which equal 10 amps. through an arc of 6 ohms. Swan lamps take 1 to 1½ amps.

'4. The quantity of electricity given by an amp. in a second is called a coulomb.'

This measurement is little used: it is derived from Faraday's law, which is expressed by the formula $q = c\,t$; *i.e.*, unit quantity is conveyed by unit current in unit time.

Measurement of Work.

The erg is the unit of work. The work done by any current per second is obtained in ergs by the product of the current into the electro-motive force producing it, or $W = CE$.

HP., or the horse power, is found by dividing CE by 746; or, $\frac{CE}{746} = HP.$

$C =$ current in ampères; $E =$ electro-motive

force in volts. This formula of work is the one which is used more than any other in determining the efficiency of any electric light. By calculating the horse power expended in the arc and subtracting it from the horse power expended in driving the machine, the amount wasted either in heating the iron of the machine or the conducting wires is discovered. The horse power may also be calculated in another way by squaring the current in ampères, multiplying by the resistance in ohms, and dividing the product by 746; thus, $\text{HP.} = \frac{C^2 \times R}{746}$

The practical application of this rule will be seen in the following account of an experiment with the Bürgin machine :—

3-Light Machine, Gross Horse Power 4·11
Internal Resistance 2·80 ohms.
External Resistance, Leading Wires 1·10
3 Lamps, including the arcs and carbons 9·36
Total external R. 10·46 ohms.

Taking the average resistance of the lamps and carbon rods to be 0·60 ohms and deducting, we get 9·36—0·60=8·76 as the net resistance of the three arcs, or about 65 per cent. of the whole resistance in the circuit.

At the time of test the current flowing in the circuit was 14·8 webers, and this through each arc of 2·92 ohms gives according to the rule—

$$HP = \frac{C^2 \times R}{746} = \frac{14{\cdot}8^2 \times 2{\cdot}92}{746} = 0{\cdot}86 \text{ horse power of energy}$$

in each arc. But as the gross horse power for each light was 1·37 some 63 per cent. of the power expended in driving the machine is obtained as useful effect in the arc. In this case the friction of the engine and shafting was omitted.

An account of some experiments made with a 16-light Brush machine, which were published by the author in *Notes on the Principal Systems of Electric Lighting*, is repeated as an illustration of the plan adopted for the electrical measurements.

The first experiments were for determining the difference of potential existing at the terminals of each lamp. This was done by the use of a battery of forty-eight small Daniell's cells constructed on the gravity plan and carefully insulated. The sixteen lamps having been adjusted to furnish arcs as nearly equal as possible, the positive terminal of one lamp was connected with the positive terminal of the battery, and the negative terminal of the same lamp with the negative end of the battery, a sensitive galvanometer being interposed. Any number of battery cells could be included in the circuit at pleasure, and such a number was

chosen that the galvanometer indicated next to no current. Each of the lamps having been measured, the difference of potential of the average lamp was thus found to be equal to 42·46 cells of the battery at an average speed of seven hundred and seventy revolutions per minute. The resistance of each lamp was then found by the ordinary method—a coil of wire—to be, when measured, 4·51 ohms. Taking the conditions of the difference of potential as above stated into account, the actual resistance of each lamp was 4·56 ohms, which, multiplied by 16, gives the total resistance of the lamp circuit, 72·96 ohms. The resistance of the machine itself was found by careful measurement to be 10·55 ohms. This resistance, added to the lamps, gives a total normal external and internal resistance of 83·51 ohms, of which 87·36 per cent., or 72·96, is external. Hence an amount of 87·36 per cent. of the current developed is available for work. The total electro-motive force of the current was then easily found to be equal to 839·02 volts, which, by Ohm's formula, $\frac{839{\cdot}02}{R}$ would make the current in circulation equal to 10·04 webers,

with a total resistance of 83·51 ohms. Calculations were made by Mr. Brush to show the amount of absorbed power converted into current, which was stated to be 81·89 per cent. Taking the percentage of current appearing as light in the arcs at 84, then 81·89 × 0·84 = 68·79 per cent. of the entire power absorbed in the production of current present is heat and light in the sixteen arcs.

The following table shows power absorbed by the machine which was taken during the progress of the electrical measurements:—

		HP.	
Total power developed with the 16-light machine at 770 revolutions 'closed'[1]		18·73	
Less friction load of engine 'light'	2·44		
" " due to increase of load (18·73 − 2·44 = 16·29) at 5 per cent.	0·81		
	——	3·25	
Total power absorbed . . .		——	15·48
Total power developed with same machine 'open' . . .		4·23	
Less friction load of engine 'light'	2·44		
" " due to increase of load (4·23 − 2·44 = 1·79) at 5 per cent.	0·09		
	——	2·53	
Total power absorbed . . .		——	1·70
" " in production of current (15·48 − 1·70 =). .			13·78

[[1] The terms 'closed' and 'open' refer to the external circuit of the machine.]

In comparing these results with the experiments with the Bürgin's machine due allowance must be made for the varying conditions under which the trials were made. In the former case the ordinary working plant was experimented with on the site of the installation, while the trials with the Brush system were carried out in the inventor's workshops.

Full accounts of the experiments made with two of the principal electric lighting systems are contained in the papers by Dr. Hopkinson. (*Vide* proceedings of the Institution of Mechanical Engineers, 1879–80.) These also include an account of the dynamometer used for ascertaining the power required for driving the machines.

USEFUL MEMORANDA

AND

TABLES.

ELECTRO-MAGNETS.

To obtain the number of turns of wire in an electro-magnet, multiply thickness of coils by length and divide by diameter of wire squared.

To obtain total length of wire, add thickness of the coils to diameter of core outside insulation, multiply by 3·14, again by the length, and again by the thickness of coils, and divide by diameter of wire squared.

To obtain resistance and weight of wires, we use one table. Covered wire varies from 1·3 to 1·6 times diameter the bare wire, according to makers.

In winding electro-magnets for shunts through the wire on which currents heavy in proportion to the diameter will be passed, it is not advisable to make the thickness of the coils more than two-thirds that of the core on account of heating.

Insulation at cheeks of magnet to be three times the thickness of that on core.

Resistances of Copper Wire for 100 *yards.*

($d =$ diameter in inches.)

Pure $\frac{\cdot 003118}{d^2}$, 98 per cent. $\frac{\cdot 003185}{d^2}$.

96 per cent. $\frac{\cdot 003265}{d^2}$, 94 per cent. $\frac{\cdot 003335}{d^2}$,

92 per cent. $\frac{\cdot 003400}{d^2}$, 90 per cent. $\frac{\cdot 003478}{d^2}$.

The resistance of any pure copper wire

$$= \frac{\cdot 001516 \text{ ohms} \times \text{square of length in inches}}{\text{weight in grains}}.$$

One mile, or 1760 yards $= \frac{\cdot 054892 \text{ ohms}}{d^2}$.

Specific gravity of pure copper, 8·899.

1 cubic foot = 550 lbs.; 1 cubic inch = 0·32 lbs.

VALUE OF COPPER CONDUCTOR AT £85 PER TON.

Diameter in inches.	Sectional Area.	Weight per Mile.			Cost per Mile at £85 per Ton.			Resistance at 96 %.	B.W.G.
		Tons.	Cwt.	lbs.	£	s.	d.	Ohms.	
1·00	·7854	7·109	..	..	604	0	0	·0575	..
·707	·3927	3·554	..	..	302	0	0	·1150	..
·500	·1963	1·787	..	..	151	0	0	·2300	..
·354	·0981	..	17·8	..	75	10	0	·4600	..
								at 98 %.	
·238	..	..	..	864	38	0	0	1·00	4
·220	..	..	..	775	34	0	0	1·16	5
·211	..	..	..	705	30	18	0	1·26	5½
·203	..	..	..	660	29	0	0	1·36	6
·191	..	..	..	580	25	9	0	1·54	6½
·180	..	..	..	515	22	10	0	1·73	
·172	..	..	..	464	20	8	0	1·89	7½
·165	..	..	..	430	18	18	0	2·06	8

No. 8 is the most convenient for stretching easily and making a neat job.

All wire for outside work should be hard drawn if for long spaces.

If used for overhead purposes the positive wire should be taped and protected, also carefully insulated at posts to prevent leakage, which is most noticeable in damp weather.

To make an electro-magnet of maximum power and of minimum resistance, or to saturate a bar of iron with magnetism without unduly heating the wire, when the E. M. F. is constant and the external R. in the circuit is fixed and given :

Formula by Thos. H. Blakesley.

$$D = \sqrt[4]{\frac{\cdot 00002 \times K^2}{R} \times \text{volume of coil in cubic millimetres.}}$$

K = the relation of the covered wire to that of the bare wire, which in the example below is about 1·4 times.

D = the value of the diameter of covered wire in millimetres.

R = external resistance in ohms.

Example: Take an electro-magnet, whose arms are 50 $^m/_m$ long each, 20 $^m/_m$ apart, and made of iron 10 $^m/_m$ diameter. The external resistance is equal to 5 ohms.

The thickness of the coil then equals 10 $^m/_m$, and its volume 63831·8 cubic $^m/_m$; multiply this by $(1\cdot 4)^2$, and the product is 123150, which, multiplied by ·00002 and divided by 5, = ·49260. The fourth root of this = ·837 $^m/_m$, which is the diameter of the covered wire, the wire itself being ·6 $^m/_m$ diameter.

NOTE.—This rule only applies to nearly pure copper. If the ordinary copper wire is used, to be perfectly accurate the value of ·00002 will require modification in proportion to the resistance of the material as compared with copper.

To find out which is the north pole of an electro-magnet :—

Observe if the wire follows the direction of a right-hand winding staircase; if so, the north pole will be at the top, if the current is supposed to be descending.

This does not apply in France, where, on account of the earth being considered a vast magnet, that pole of a magnet which would turn to its north is called the south pole. In fact, the French south pole in a magnet is our north.

To ascertain in which direction the electric current is flowing by means of a compass :—

A current flowing from south to north will always deflect the needle to the west, providing the wire in which the current flows is over the instrument. The word S.N.O.W. expresses this—south, north over west—and should be remembered.

Note on Electric Currents.

It has been shown by Professor Forbes that if two conductors are close together, the radiating surface from one to the other has to be taken into account. He finds by experiment that if there is a departure from the law of the square of the diameter, the law is almost proportional to the diameter of the wire; *i.e.*, if a wire 1 $^m/_m$ diameter will carry a certain amount of current without heating it over 150°, to carry a current of twice the intensity will require a wire of 2 $^m/_m$ in diameter; *i.e.*, of four times the area.—*Engineering, Sept. 22nd*, 1882.

Current = C in ampères.

E = EMF. of machine in volts.

R_1 = resistance of machine in ohms.

R_2 = resistance of lead in ohms.

R_3 = resistance of lamps, carbons, cut-outs, and arcs in ohms.

$$C = \frac{E}{R_1 + R_2 + R_3}.$$

With Arc Lamps:—

When 1 only is used

R_3 = from 1 ohm to 1·4.

When 2 are burned in series

R_3 = from 4 to 5 ohms.

When 3 are burned in series

R_3 = from 8 to 10 ohms.

When 4 are burned in series

R_3 = from 10 to 12 ohms.

With Incandescent Lamps:—

$$R = \frac{\text{Resistance of a single lamp hot}}{\text{Number of lamps in parallel circuit}}.$$

		Electro-motive Force.		Extreme safe currents.
B Bürgin at	1550 revs.	200 volts	.	21 ampères.
B′ ,,	1550 ,,	160 ,,	.	25 ,,
C ,,	,, ,,	300 ,,	.	21 ,,
C_2 ,,	,, ,,	160 ,,	.	35 ,,

EMF. is directly proportional to speed between 1000 and 1700 revs.

ENGLISH AND FRENCH MEASURE.

Millimetre	= 0·039 inches		1 mil.	=	·0254 millimetres.
Centimetre	= 0·393	„	1 inch	=	2·5399 centimetres.
Decimetre	= 3·93	„	1 foot	=	3·0480 decimetres.
Metre	= 39·37	„	1 yard	=	·91439 metres.

CARBONS AND CHEMISTRY.

If 13mm. diameter carbons of good quality are burned with a current of 75 ampères, the light is about equal to 400 gas burners each using 500 cubic feet per hour.

The weight of carbon burned is ·79 oz. per hour. This requires 2·11 oz. oxygen = 1·57 cubic feet.

If we have a ·25-inch diameter crater in positive carbon, we must deduct 15 per cent. of the above, giving 1·32 cubic feet per hour oxygen combined by the electric arc into carbonic acid.

Morin gives 580 units as available for heating surrounding atmosphere by combustion of 1 cubic foot of gas.

∴ a burner using 5 cubic feet per minute gives off 48·5 units of heat per minute.

1 HP. = 42·5 units. ∴ the above arc, using a current of 25 ampères, will not heat a room so much as one 5-foot burner, the light being 400 to 1.

TO OBTAIN THE MAXIMUM LIGHTING AND ACTINIC EFFECT FROM AN ELECTRIC ARC.

Use the smallest carbons possible for the current. Judge of this by the size of crater produced and the length of cone on each carbon. Increase diameter only

so far as to obtain as large and true a crater as possible.

By a true crater is meant one with only one curvature. If the crater is divided off into several curvatures or facets it is a false one, and the current does not use the whole of it at one time. When this is the case diameter of carbon should be reduced.

LENGTH OF ARC.—This should be as short as possible, so that the light gets out (*i.e.*, is not smothered by mushrooms, &c.).

Regulate the length so as to get the arc just beyond hissing. If it be close on hissing it is at point of highest temperature.

Hissing is caused by extreme temperature.

Hissing means a violent boiling and translation of particles of pure carbon. It never takes place whilst there are any impurities in the arc more easily volatilisable than the carbon itself. Whenever the arc distils itself free from such impurities, if the temperature is high enough, hissing will take place. Hissing is generally accompanied by momentary decrease of the arc resistance, consequent increase of current, temperature, and light.

The hissing renders the light somewhat unsteady, so that although there is actually more light it will not measure so high in the photometer.

Just previous to, or just after, the arc hisses are the times of highest photometrical efficiency.

The preceding memoranda were published in the Supplement of the ELECTRICIAN.

ELECTRICAL TABLE OF THE BIRMINGHAM WIRE GAUGE FOR COPPER.

B.W.G. No.	Diameter in Inches.	Diameter in Millimetres.	Area in Square Inches.	Circumference in Inches.	Pounds per Mile.	Feet per Pound.	Feet per Ohm.	Ohms per 1000 Feet.
1	·3	7·62	·070686	·94248	1444·0087	3·662	8706·843	·1148
2	·284	7·21	·063347	·89221	1291·8699	4·0988	7803·51	·1282
3	·259	6·58	·052685	·81367	1074·5697	4·9262	6490·09	·1540
4	·238	6·04	·044488	·74770	907·3683	5·850	5580·01	·17007
5	·22	5·59	·038013	·69115	773·045	6·83	4681·1	·2136
6	·203	5·16	·032365	·63774	657·205	8·02	3985·7	·2509
7	·180	4·57	·025447	·56549	517·493	10·20	3134·8	·3190
8	·165	4·19	·021382	·51836	434·861	12·14	2633·7	·3797
9	·148	3·76	·017203	·46495	349·853	15·10	2119·9	·4719
10	·134	3·40	·014103	·42097	286·651	18·44	1737·0	·5757
11	·120	3·05	·011309	·37699	229·997	22·95	1392·9	·7179
12	·109	2·77	·009331	·34243	189·763	27·82	1149·4	·8700
13	·095	2·41	·007088	·29845	144·144	36·63	873·1	1·1454
14	·083	2·11	·005411	·26075	110·035	47·98	665·3	1·503
15	·072	1·83	·004071	·22619	82·790	63·77	501·5	1·9941
16	·065	1·65	·003318	·20420	67·478	78·25	408·7	2·4466
17	·058	1·47	·002642	·18221	51·3163	102·89	310·8	3·2176
18	·049	1·24	·001886	·15394	38·3486	137·68	232·3	4·3052
19	·042	1·07	·001385	·13195	28·1741	187·40	170·6	5·8599
20	·035	·89	·000962	·10995	19·5677	269·83	118·5	8·4381
21	·032	·81	·000804	·10053	16·3574	322·79	99·1	10·094
22	·028	·71	·000616	·08796	12·5242	421·58	75·8	13·185
23	·025	·63	·000491	·07854	9·9845	528·82	60·5	16·539
24	·022	·55	·000380	·06911	7·7299	683·06	46·8	21·357

EXPLANATION OF TERMS.

Ampère.—The unit of current.

Battery.—A combination of two or more voltaic cells coupled together in series.

Bobbin.—A coil of wire or a number of such coils so mounted that they can be rapidly revolved.

Bridge (Wheatstone's).—An apparatus for measuring resistances by balancing the unknown resistance against one known and capable of adjustment.

Candle Power.—Term used to denote the amount of light as compared with a standard sperm candle.

Carcel Lamp.—The French standard, equal to 9·4 candles.

Cell.—Each separate vessel in which a chemical action occurs, by which electricity is capable of being developed.

Circuit Conductive.—The wires which form the path for the passage of the current.

Commutator.—A circuit changer, or switch.

Coulomb.—Unit of quantity.

Conductivity—Is the reciprocal to resistance, and applies to that property of any substance whereby the passage of electricity through it is effected with the least opposition.

Conductors.—Substances which most freely permit electricity to pass.

Connections.—Wires, &c., completing the circuit below the lines and different apparatus.

Current.—The supposed flow or passage of electricity or electrical force in the direction from + to —, or positive to negative.

Current Reverse.—A current in the opposite direction to the normal current.

Deflection.—The angle or number of degrees through which the needle of a galvanometer moves when a current is passing through its coils.

Duty.—A term used to denote the economy of any motor.

Dynamometer.—An instrument for ascertaining the horse power absorbed by any machine.

Electro-meter.—An instrument for measuring electric potential.

Electro-motive Force (EMF.).—The force which develops electric tension or potential.

Galvanometer.—An instrument for measuring current.

Governor.—An apparatus for controlling the speed of any motor.

Horse Power (HP.)—indicated HP.—Is 33,000 lbs. lifted one foot high per minute. The nominal HP. of any motor is generally fixed considerably less than the indicated.

Indicator Diagram.—The drawing produced by an instrument which is fixed to the cylinder of a steam engine for the purpose of ascertaining its horse power.

Induction.—The name given to effects produced out of a force exerting body out of the circuit to which the force is directly applied.

Insulators.—Bodies possessing high electrical resistance. All insulating substances, however, allow some electricity to pass.

Intensity.—The old term for the properties now described as EMF. and potential.

Magnetism.—A condition of electrical action which can be highly developed in iron and steel.

Measurement.—See Units.

Metre.—The French standard of length = 3·28 feet.

Negative.—In a machine the wire returning from the lamp. In the battery the copper, carbon, or platinum plate.

Ohm.—The unit of resistance.

Ohm's Law.—Formula devised by Ohm for calculating unknown electrical magnitudes: Calling the current C, electro-motive force E, and resistance R, the expression is $C = \frac{E}{R}$

Plummer Block.—The bearing on which a shaft revolves.

Polarity.—The distinct features of the two separate poles of a magnet.

Poles.—The two ends of a magnet. The wires, plates, &c., leading from a battery.

Positive.—In a machine the wire proceeding to the lamp. In the battery the zinc plate.

Potential.—A word used to indicate a condition for work. Difference of potential is a difference of electrical condition.

Resistance.—The opposition presented by the circuit to the development of the current.

Return Current.—The current in the wire leading to the machine.

Rheostat.—A variable artificial resistance employed for measuring unknown resistances.

Rigger.—The pulley or wheel by which power is transmitted.

Spectrum.—The elongated figure of the prismatic colours.

Shunt.—A resistance coil of wire arranged to take a certain proportion of any current.

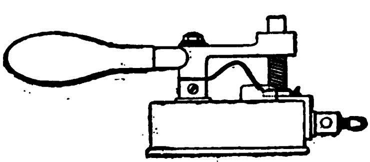
Units.—The various bases of any system of measurement.

Unit of Force.—That force which would produce in one second in a body weighing one gramme a velocity of one metre per second.

Volt.—The unit of electro-motive force.

Voltameter.—An apparatus for measuring the current by its chemical action.

Weber.—The old term for the unit of current.



THE ELECTRIC LIGHTING BILL.

The electric lighting bill is now on the statute book, but so far the anticipations as to the extension of the supply of electricity have not been realised. Both the promoters, or, as they are called, the 'undertakers,' of the various schemes and the local authorities have genuine grievances which help to postpone the general supply of the light to the public.

The Electric Lighting Act has been passed with the especial view of preventing the establishment of a monopoly. More than one undertaking may be authorised in the same area, and it should not be overlooked that, if the system proves successful in a limited area, the corporation may apply for powers to supply in such area or in the remainder of the borough.

A license can only be granted with the consent of the local authority, and only for seven years, nor can it be renewed without their consent. A provisional order granted to a private company may be terminated by purchase of the electric plant on favourable terms by the local authority at the end of twenty-one years, by giving six months' notice, or the purchase may be made on such shorter term as parliament may impose.

Little profit can be expected by the contractors from the supply of electricity for the first seven years. And the time given for compulsory purchase is very short, considering the arbitrary nature of the sale which the

bill specifies is not to take any account of goodwill or allowance for the compulsory sale.

In spite of the apparent drawbacks to the extension of electric lighting from a commercial point of view, the principal companies have given due notice to all the local authorities of their intention to apply for a license under the terms of the act. The local authorities, however, are not prepared to entertain their proposal, and have, with a few exceptions, opposed the electric lighting companies.

To a certain extent, the latter are acting rightly, looking at the matter from their point of view, which is, to provide the borough under the jurisdiction with the most improved and reliable light, without the annoyance to the ratepayers of having the streets frequently taken up, in the instance of rival private companies.

Probably the best way to effectually prevent this, and, at the same time, to facilitate the introduction of electricity, would be for the local authorities themselves to lay down the necessary mains, wires, &c., throughout the section of the town which it was proposed to light. These mains would be provided with suitable boxes at intervals, where the wires could be tapped for household supply. Such an electric main, which would enable the local authorities to have control of the streets, could be led from the site deemed most suitable for the generating station, and might be handed over to the contractors for the experimental or permanent lighting. Its gauge would be calculated to take sufficient current to supply the district at a determined electrical pressure, so as to give the required electro-motive force without danger.

Cost of Electric Plant.

The cost for the supply of an ordinary town was variously estimated in the proceedings before the committee of the House of Commons.

Dr. Siemens took from 80,000 to 100,000 incandescent lamps and 280 arc lamps per square mile at a cost of £400,000.

Mr. Crompton, 50,000 Swan incandescent lamps per square mile, £200,000.

Dr. Hopkinson, 50,000 Swan incandescent lamps per square mile, £200,000.

Mr. Johnson, 50,000 Edison incandescent lamps per square mile, £150,000 to £200,000.

Although the estimates differ, with the exception of Dr. Siemens, they practically agree to a capital account of £4 per lamp, if the number of lamps are taken as the measure of the cost. A comparison with the cost of laying down a plant for the supply of gas shows that the estimate of £4 per lamp is not enough, and would probably make the first outlay for an electric plant considerably higher than that for gas. A wide difference, however, exists as to the actual value of the material used. An estimate of the break-up value of a gasworks and mains would be very low indeed, while, on the contrary, the steam engine or motor of an electric light installation would always command a good price in the market, while the value of the copper in the mains and wires of the dynamos would hardly be depreciated at all. Another point must be considered, which is;—a system of electric distribution, not only enables

us to acquire light, but also power; so that instead of the plant remaining idle throughout the day the electric current, as a means of transmission of power, could be put to minor uses in a very inexpensive and efficient manner. Hoists can be worked, sewing machines, lathes, and looms have already been driven by small electro-motors, selling at the present time for about 30s. each and upwards, which from the absence of complicated working parts will cost for renewal and repairs less than the oil consumed in the gas engine they are destined to supersede at an early date.

RULES OF THE COMMITTEE ON FIRE RISKS FROM ELECTRIC LIGHTING.

Adopted by Order of the Council of the Society of Telegraph Engineers and Electricians, June 21st, 1882.

These rules and regulations are drawn up, not only for the guidance and instruction of those who have electric lighting apparatus installed on their premises, but for the reduction to a minimum of those risks of fire which are inherent to every system of artificial illumination.

The chief dangers of every new application of electricity arise from ignorance and inexperience on the part of those who supply and fit up the requisite plant.

The difficulties that beset the electrical engineer are chiefly internal and invisible, and they can only be effectually guarded against by 'testing' or probing with electric currents. They depend chiefly on leakage,

undue resistance in the conductor, and bad joints, which lead to waste of energy and the production of heat. These defects can only be detected by measuring, by means of special apparatus, the currents that are either ordinarily, or for the purpose of testing, passed through the circuit. Bare or exposed conductors, where the accidental falling on to, or the thoughtless placing of, conducting bodies might lead to 'short circuiting' or the sudden generation of heat due to a powerful current of electricity in conductors too small to carry it, should always be within visual inspection.

It cannot be too strongly urged that amongst the chief enemies to be guarded against are the presence of moisture and the use of 'earth' as part of the circuit. Moisture leads to loss of current and to the destruction of the conductor by electrolytic corrosion, and the injudicious use of 'earth' as a part of the circuit tends to magnify every other source of difficulty and danger.

The chief element of safety is the employment of skilled and experienced electricians to supervise the work.

I. The Dynamo Machine.

1. The dynamo machine should be fixed in a dry place.

2. It should not be exposed to dust or flyings.

3. It should be kept perfectly clean and its bearings well oiled.

4. The insulation of its coils and conductors should be perfect.

5. It is better, when practicable, to fix it on an insulating bed.

6. All conductors in the dynamo room should be firmly supported, well insulated, conveniently arranged for inspection, and marked or numbered.

II. The Wires.

7. Every switch or commutator used for turning the current on or off should be constructed so that when it is moved and left to itself it cannot permit of a permanent arc or of heating, and its stands should be made of slate, stoneware, or some other incombustible substance. (*See* figs. 1 and 2, page 37.)

8. There should be in connection with the circuit a safety fuse constructed of easily fusible metal which would be melted if the current attain any undue magnitude, and would thus cause the circuit to be broken. (*See* illustrations 1 and 2, page 165.)

9. Every part of the circuit should be so determined that the gauge of wire to be used is properly proportioned to the currents it will have to carry; and changes of circuit, from a larger to a smaller conductor, should be sufficiently protected with suitable safety fuses, so that no portion of the conductor should ever be allowed to attain a temperature exceeding 150° F.

N.B.—These fuses are of the very essence of safety. They should always be enclosed in incombustible cases. Even if wires become perceptibly warmed by the ordinary current, it is a proof that they are too small for the work they have to do, and that they ought to be replaced by larger wires.

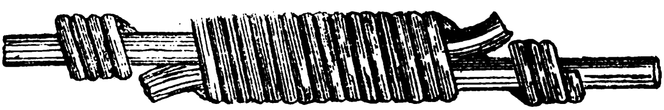
10. Under ordinary circumstances complete metallic

circuits should be used, and no connection with gas or water pipes should be admitted.

11. Where bare wire out of doors rests on insulating supports, it should be coated with insulating material, such as india-rubber tape or tube, for at least two feet on each side of the support.

12. Bare wires passing over the tops of houses should never be less than seven feet clear of any part of the roof, and they should invariably be high enough to allow fire escapes to pass under them where crossing thoroughfares.

13. It is most essential that the joints should be electrically and mechanically perfect. One of the best joints is that shown in the annexed sketch. The joint is whipped around with small wire, and the whole mechanically united by solder.



14. The position of wires when underground should be carefully indicated, and they should be laid down so as to be easily inspected and repaired.

15. All wires used for indoor purposes should be carefully insulated.

16. When wires approach each other, as through roofs, floors, walls, or partitions, or where they cross or are liable to touch metallic masses, like iron girders or pipes, they should be thoroughly protected from each other and the metallic masses by some additional insulating material.

17. Where wires are put out of sight, as beneath flooring, they should be led through properly arranged

tubes of glass, porcelain, earthenware, or other analogous substance, and their position should be marked, and where they are liable to abrasion or to the depredations of rats or mice they should be efficiently encased in some hard material.

N.B.—The value of testing the wires frequently cannot be too strongly urged. It is an operation, skill in which is easily acquired and applied. The escape of electricity cannot be detected by the sense of smell, as can gas, but it can be detected by apparatus far more certain and delicate. Leakage, not only means waste, but in the presence of moisture it means destruction of the conductor and its insulating covering, by electric action.

III. Lamps.

18. Arc lamps should always be guarded by proper lanterns to prevent danger from falling incandescent pieces of carbon and from ascending sparks. Their globes should be protected with wire netting.

19. The lanterns and all parts which are to be handled should be insulated from the circuit.

IV. Danger to Person.

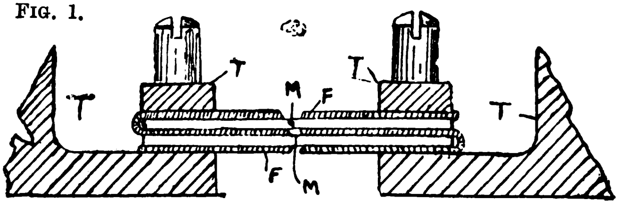
20. To secure persons from danger inside buildings, it is essential so to arrange the conductors and fittings that no one can be exposed to the shocks of alternating currents exceeding 60 volts, and that there should never be a difference of potential of more than 200 volts between any two points in the same room.

These rules have been adopted in a slightly altered form by the Phœnix Insurance Company, who recommend

a lead 'cut-out' being placed when practicable at every light.

The value of this arrangement is annulled by reason of the uncertainty of lead as the fusible material. Tin or platina foil is found to be more reliable, and if a 'cut-out' so composed be inserted in the circuit leading to each room, complete safety would be attained. To avoid all the lights in the room being extinguished or the circuit being ruptured, it would be advisable to have two independent circuits for each number of lights.

FIG. 1.



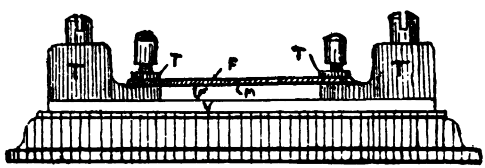


FIG. 2.

Figs. 1 and 2 show the construction of Hedges' 'cut-out' for fixing in the main circuit, and through which the whole of the current has to pass. (Fig 1 shows foil melted.) It consists of alternate plates of mica, M, and tinfoil, F, the number of the latter varying according to the desired working strength of the current. By enclosing the foil in separate pieces of mica each takes its share of the current, and from its small area does not have the disadvantage attending the fusion of a rod of lead. (Fig. 2, foil enclosed between two mica plates.)

MACHINES FOR THE SUPPLY OF ELECTRICITY.

The Ferranti and the Gordon Dynamos.

Given a demand for electricity and efficient arrangements for its distribution from central stations, the question arises as to which would be the best form of dynamo to employ;—either one of large size, capable of supplying a whole district, or several smaller ones coupled together so as to perform the same amount of work.

It was originally proposed in the Edison system to use several dynamos so disposed that if one of the series should break down or be switched out the effect would be to reduce the quantity of electricity put into the mains by that amount. In the case of a breakdown the engine could be urged and the remaining machines instantly caused to produce an extra amount of current. Larger machines are found to be less expensive to work, as they can be connected direct to the engine, so that the most recent installations on the Edison system have been with very large dynamos, generating sufficient electricity for a great number of lights. A rage for large dynamos has set in, and considerable stir has been made recently by the announcement of a new machine called, after the inventor, the 'Ferranti,' which is intended to work 2000 to 2500 lamps. The statements as to the efficiency of this machine are such as cause some

surprise as to how the results given are attained. The Ferranti machine is announced to be capable of maintaining "11 to 12 lights of 20 candles each, or 220 to 240 candles per horse power in regular work as against eight to ten 20-candle lights, or 166 to 200 per horse power for machines of existing types." As dynamos have already been shown to have a theoretical duty of 90 per cent, it is simply impossible to produce a machine that will return in electrical energy for lighting purposes more than 90 per cent of the power put into it.

The inventor has certainly succeeded in designing a very compact low tension machine, and one which will run a large number of lamps in a satisfactory manner with an alternating current; but it is a question whether any great increase of efficiency is obtained. A dynamo has recently been exhibited maintaining 300 incandescent lamps with an expenditure of 26 horse power, and a total E.M.F. of 125 volts at 1900 revolutions per minute. If these lamps were of 20 candle power the result would be approaching 240 candles per horse power; but the actual candle power of each of the 300 lamps exhibited was probably nearer 15, which would give a duty of about 173 candles per horse power. The outward appearance of the Ferranti machine is very much like that of a Siemens alternating; also the disposition of the revolving sector-shaped coils appears to be a modification of the Siemens armature, a copper strip being used instead of wire.

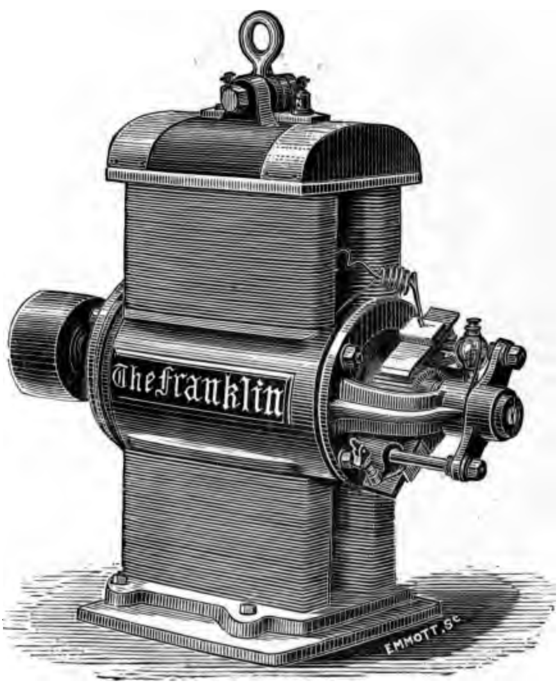
The Ferranti dynamo is said to be constructed on the Arago disc principle; but with the exception of the coils being revolved in a very intense magnetic field, the form of the design in reality has very little in common with

the copper disc of Arago as illustrated by Faraday's experiment in 1831, with a copper disc revolved between the poles of a horse-shoe magnet. This early experiment showed the existence of currents flowing from the centre to the circumference of the disc as soon as the latter was rotated before the poles of a magnet, so as to cut the magnetic curves at right angles. The dynamo exhibited by the Whitehouse Mills Company at the Crystal Palace Exhibition proved that a simple form of alternating current machine might be made on this principle; the great drawback of applying it for a continuous current would be the necessity of having a collector at the periphery of the disc. The latter must of necessity be of great diameter if the machine is to be capable of maintaining a large number of lights, so that it would be almost impossible to make any arrangement of brushes or rollers collect the currents in a satisfactory manner.

Another new dynamo, invented by Mr. J. C. H. Gordon, has lately been tried, and promises to be far more valuable than the Ferranti machine, which is open to objection because of its high speed. Gordon's machine consists of a large wheel of boiler plate, on the outer edge of which on both sides are fixed a row of magnet coils. This is arranged so as to revolve in front of a number of armature coils fixed to rings on each side of the wheel. The diameter of the magnet wheel is 8 ft. 9 in., and its weight is 7 tons: no commutator is used, as the current is alternating. It is coupled direct on to the steam engine, and is revolved at the rate of 140 revolutions per minute, which gives a velocity of about 60 feet per second to the magnets on

the wheel. The electro-magnet coils are excited by a Bürgin machine, and it is then capable of maintaining 1300 20-candle Swan lamps, two in series, whose resistance is about 32 ohms hot, requiring a current of 1·4 ampère and an E.M.F. of 45 volts. By altering the disposition of the armature coils any number of lamps may be worked up to 5000.

The trial which recently took place was considered a success, but the general opinion was that two machines of less power would be far more useful, especially if each were worked at about two-thirds of their actual power, so as to allow for a reserve in case of an accident to one of them.



THE FRANKLIN-BÜRGIN MACHINE.

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